ON

THE NATURE AND TREATMENT

OF

THE DISEASES

OF THE

HEART.

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OF THE

HEART;

WITH SOME NEW VIEWS

ON THE

PHYSIOLOGY OF THE CIRCULATION;

BY

JAMES WARDROP, M. D.

SURGEON TO HIS LATE MAJESTY, GEORGE IV.; LECTURER ON SURGERY,
&c. &c. &c.

LONDON:

JOHN CHURCHILL, PRINCES STREET, SOHO.

1837.

PRINTED BY WILLIAM NICOL, 51, PALL MALL.

PREFACE.

The First Part of this work contains Preliminary Observations on the structure and functions of the Heart, with which are interspersed some new Physiological Researches on the Circulation.

The Second Part will give an account of the Diseases of the Heart, and those affections will be more especially treated of, which are of common occurrence, and which we have the means of alleviating by medical treatment,—but comparatively little will be said of those morbid changes which seldom occur, or over which the resources of medicine have been found to exercise little controul.

Whilst prosecuting some investigations concerning the Diseases of the Heart, and more particularly regarding their causes and treatment, the author's attention was directed to certain symptoms with which various affections of that

organ are accompanied,—and, in seeking an explanation of them, he was led to reflect on several natural phenomena connected with the circulation of the blood in the Heart, and with the function of respiration, but of which no satisfactory explanation could be found, and to some of which even no allusion had been made in physiological writings.

He was particularly struck with the influence of respiration on the action of the Heart, and with the influence of the action of the Heart on respiration, as well as with all the modifications of these functions, not only in diseases but likewise during the acts of weeping—sobbing—crying—laughing—in the giddiness experienced in turning round rapidly,—in swinging and in sea sickness.

His attention was not less arrested when contemplating the influence, which the almost constant movements of the body exercise both on the respiratory and the circulating organs. He was led to enquire how the action of the heart and lungs is increased by violent exercise,—how persons can by a process of "training" acquire the power of using their muscles, until their muscular energy is exhausted, without causing breathlessness or a sense of suffocation,—in what the art of diving consists—and finally, how dis-

eases of the heart are caused by violent muscular exertions and by mental excitement.

Having arrived at the conclusion, that these various phenomena are intimately connected with the great function of the circulation of the blood, further observations convinced the author, that each of these different acts is employed for performing a specific purpose in the economy,—some for increasing and others for diminishing the quantity of blood within the thoracic cavities, according as modifications in the quantity of blood are required, or an adjustment becomes necessary in different organs for the due performance of their respective functions.

In pursuing these investigations, the mind was conducted step by step to establish the existence of three important functions,—functions connected with the circulation of the blood, which had hitherto been overlooked by physiologists.

First,—*that the Muscles, besides being the active organs of locomotion, perform the important office of increasing the quantity of arterial as well as of venous blood, within the cavities of the heart.*

Secondly,—*that the Lungs regulate the supply of blood to the heart so as to prevent congestion within the heart's cavities ; and*

Thirdly,—*that the Subcutaneous Veins per-*

forming the office of a reservoir, prevent congestion of blood within the pulmonary vessels.

By establishing these important functions,—of the organs of active motion,—of the lungs, and of the subcutaneous veins—several phenomena, both of the respiratory and circulating organs, admit of a satisfactory explanation; and we are enabled to account for some peculiarities in the structure of the vascular system, whilst we are, at the same time, materially assisted in the elucidation of many phenomena, in the diseases both of the circulating and respiratory organs.

The Second Part of this work will give an account of the Diseases of the Heart and their Treatment.

From the supposed dangerous tendency of all the diseases of the Heart, we might have anticipated that the various affections of that organ would have been carefully investigated, even from a very early period in the history of medicine. But the erroneous impression of the limited powers of medical treatment, as well as of the fatal character of these diseases, would seem to have paralysed, rather than excited enquiry into this most interesting branch of medical science.

Morgagni, Senac, Baillie, Burns, *and*

others, had contributed much to advance our acquaintance with the Pathology of the Heart; but the subsequent researches of the French Pathologists, more especially those of Corvisart, Laennec, Bertin, Andral, *and* Bouillaud, *by pointing out the means of recognising, during life, those various morbid changes of structure which we had previously been able to detect only after death, materially contributed to the advancement of this department of knowledge. Still however it remains an important desideratum, to discover the means of discriminating diseases of the heart in their earliest stages, and before any of those formidable changes of structure have taken place, which it is not within the powers of medicine to relieve. It is quite evident that such changes of structure must be preceded by a train of phenomena, and by a series of lesser disturbances in the function of the heart, and the detection of these will enable us to apply remedial means, with a probability of achieving the same advantages, as in the treatment of diseases in other organs.*

We may also anticipate a great extension of our knowledge of curative means in the treatment of Diseases of the Heart, since there is a class of medicines, which, from their specific influence on the organs of the circulation, may

be advantageously employed in these various affections.

Ipecacuanha, as is well known, acts upon the stomach,—saline medicines on the small, and aloes on the large intestines,—mercury influences the functions of the liver and salivary glands,—cantharides and the various balsams operate on the urinary organs,—narcotics act on the brain, and some even on particular nerves, as for instance belladonna on those of the iris. In like manner, the preparations of antimony, of iron, of lead, and also some vegetable substances, as digitalis, colchicum, hellebore, and tobacco, have each a particular influence on the functions of the Heart. It is not therefore too much to affirm, that the power of recognising diseases of the Heart in their earliest stages, will, combined with the judicious exhibition of these various remedies, afford the means of treating the diseases of that organ as successfully as those of any other diseased viscera.

Charles Street, St. James's Square.
May, 1837.

PRELIMINARY OBSERVATIONS.

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Before making any observations on the particular diseases of the heart, it may be well to review some of those striking peculiarities in the natural structure and functions of this important organ, to which I shall have occasion more especially to allude, as our pathological investigations require a constant reference to its healthy condition.

The muscles of the heart.

Destined to propel the blood not only to the lungs, but throughout the whole system, the heart is endowed with a *muscular structure*, and this forms perhaps the most essential ingredient in its composition. The muscles of the heart are generally more firm and more elastic than other muscles; and the fibres of which they are composed are more compact, being separated only by a very delicate cellular tissue.

Excited to contract by the blood.

The heart's muscles are excited to contract by the blood, in like manner as muscles of other organs are stimulated by the respective fluids which are naturally in contact with them, as in the instances of the alimentary canal, and the urinary bladder.

Their peculiarities.

The muscles of the heart are also remarkable for having an unusual number of blood-vessels when compared with those of other muscles, an additional quantity of blood being required to enable them to perform their unceasing actions.

Their actions are unceasing.

There is, however, one essential difference in the function of the muscles of the heart from those of all other organs; they *have no repose!* their unceasing action being absolutely necessary for the continuation of life. "How is it," says the illustrious HALLER, "that the heart, with its incessant motion during so many years as there are in a life-time, during so many days as there are in a year, and when in each hour it contracts not much less than five thousand times, never resting, but contraction perpetually succeeding repletion,—how is it that the heart is neither fatigued nor pained by so excessive an action, an action which no other muscle could endure even for a few hours?"

Haller's First Lines of Physiology, Edinb. 1801.

Diseases of the heart's muscles frequent.

Now it is this difference in the function of the muscles, to which I think may be attributed

many of the peculiar features in the diseases of the heart, and it is also this muscular part of its structure which is found to be most frequently affected.

Peculiarity in their treatment.

With regard to the muscles of the heart, it is easy to comprehend how, when they have been excited to inordinate action, the circumstance of their having no repose to enable them to recover the effects of fatigue must ultimately create changes in their structure, as well as in their function, which would not occur in muscles which can be placed in a state of perfect rest after violent exertion. And, as shall afterwards be pointed out, when the heart's muscles have been over-excited or fatigued, a circumstance which is often taking place, they require a distinct system of treatment.

Action of the heart modifies all its diseases.

This unceasing action of the heart has, as might have been anticipated, an indirect influence in modifying the diseases of all the textures which enter into the composition of this organ; for, when either its external covering or its internal membrane becomes in the slightest degree inflamed, that inflammation cannot fail to be increased by the unremitting action of its muscles.

The yellow fibro-cartilaginous structure.

In the composition of the heart there is also a considerable quantity of the *yellow fibro-carti-*

laginous substance similar to the fibrous coat of the arteries. This structure commences at the roots of the large vessels where they emerge from the heart's cavities, and by its elasticity it assists these cavities alternately to expand and contract, and thus to accommodate themselves to the constant changes in the quantity of blood which is propelled into them.

See Appendix A.

The external and internal membrane.

Besides the muscular and fibro-cartilaginous structures, the heart has a serous capsule, or *pericardium,* which covers it externally, and all the cavities are lined by a serous membrane or *endocardium,* the auricular portion presenting a structure similar to that lining the veins, and the ventricular portion having a lining membrane resembling that of the arteries.

The arteries of the heart.

The *coronary arteries* of the heart are not only of larger dimensions than other arteries, in proportion to the bulk of the muscular structure which they supply, but they present a striking peculiarity in their trajet. These vessels, in place of being encircled by muscles, pass along the tendinous and deep grooves which separate the auricles from the ventricles, by which simple contrivance neither the arteries nor the veins can suffer any compression either from the auricular or ventricular contractions.

See Appendix B.

The two coronary arteries supply not only

the muscular structure of both auricles and ventricles, and the coats of those portions of the large arterial trunks which are within the pericardium, but some of their branches are also reflected on the pericardium itself. These arteries by inosculating with branches of the internal mammaries, and with the bronchial vessels, establish a vascular connection amongst the different structures of the heart, a connection which is exemplified in many diseases.

In general, throughout the system, it may be observed, that the blood in the veins flows in an opposite direction to that in the arteries, so that the two streams of blood are, as it were, opposed to each other. But, in the heart, the current of the blood in the large branches of the coronary veins, which vessels are placed alongside of the coronary arteries, runs in the same direction with the blood in the arteries.

See Appendix C.

The heart has a smaller proportion of *nerves* than many other organs, and these being derived both from the great sympathetic and ganglionic system explains the influence which the mind exercises on the heart, as well as its sympathies with the respiratory and digestive apparatus.

The nerves of the heart.

Independently of these diseases which are confined to either the pulmonic or systemic heart, each of the heart's structures is liable, as

The diseases of the heart.

in other organs, into the composition of which such tissues enter, either to be affected separately, or they may be all involved in one disease; and, whenever any part of the structure of the heart is changed, some of its functions become disturbed, and various alterations take place in the distribution of the blood. If, for example, from any change of structure, the blood cannot readily pass from the right auricle into the right ventricle, or from the right ventricle into the pulmonary artery, it will be naturally expected that either of these changes will produce some irregularity in the distribution of the *venous* blood. So, also, a variety of symptoms will arise from a disturbance in the circulation of the *arterial* blood, when either the left auricle or the left ventricle cannot propel the blood in its natural current, or with its usual velocity.

Heart not alone sufficient for carrying on the circulation.

On contemplating the structure and function of the central organ of the circulation for the purpose of elucidating the nature of its various diseases, it is essential that our researches be not limited to the function of the *heart* alone, but that such enquiries be extended to those other organs which are intimately connected with the heart, and which materially contribute to the circulation of the blood.

Though it may be strictly true that the blood

flows in a circle, and that the heart, like a syringe, propels the sanguineous fluid throughout the whole system, there are other physical conditions, necessary for the due performance of that important function—conditions to which we must constantly refer in all our pathological researches.

Variations of supply to different organs.

It is not only indispensable that a certain *quantity* of the blood be sent to every part of the body, but it is also requisite that the supply to different organs be variously *modified.* In some it is requisite that such supply be always equal and uniform, whilst, in others, it is necessary that the quantity of the blood can be either diminished or increased.

Supply to the Brain uniform.

Of the first of these conditions there is an example in the brain; to which, for the due performance of the intellectual functions, the supply of blood must be always uniform; and of the other we have an illustration in the stomach, to which viscus, during the process of digestion, the quantity of blood is more or less increased.

To the Stomach varied.

And in the Erectile Tissues.

Another illustration of a temporary change in the quantity of blood in particular organs is afforded in the *erectile tissues,* this structure being employed in certain organs for the sole purpose of altering their form in order to enable the or-

gans to which they belong to perform a particular function. Thus the erectile tissue of the nipple becomes injected with blood to enable the infant to withdraw the milk from the lacteal tubes.

Organs employed besides the Heart in the circulation.

For thus regulating the distribution of the blood throughout the system, we shall find that there are employed no less than five other organs besides the heart ; these are the arteries,—the capillaries,—the veins,—the muscles or active organs of motion,—and the respiratory apparatus.

The Arteries.

The *arteries,* whether by an elastic power alone, or by elasticity and muscularity combined, lend the heart an important aid in conveying the blood to the capillaries. I have already stated that it is not requisite that the blood be transmitted to all parts of the body with the same velocity, or that the supply to different organs be at all times uniform. These purposes, as well as to provide for the exigencies which certain organs may demand, when, from our habits or avocations the circulation becomes disturbed, are all fulfilled by particular modes in the distribution of the arteries.

Differ in their mode of Distribution.

The length of different arterial trunks,—the different angles at which the branches leave the trunks,—the varieties in the course or trajet of arteries,—the different modes in which they

ramify,—and the anastamoses of arteries, are all peculiarities which are contrived to modify the circulation of the blood in particular organs.

A remarkable difference in the *length* of arteries as well as in the *angle* by which they come off from the trunk, is exemplified in the renal and spermatic vessels, whilst the carotids and vertebrals, and particularly the rete mirabile in quadrupeds,—the arteries of the uterus and of the spleen, and the distribution of the brachial and femoral arteries in the tardigrade animals are each examples of *tortuosities* in the distribution of arteries, obviously intended either to modify the momentum of the blood or to insure a regular supply to particular organs,—such modifications in the blood's circulation being required for the performance of the various functions of the œconomy.

See Appendix D.

The *anastomoses* of arteries, as that formed by the coronary arteries of the heart, stomach, and lips, and by the arteries of the iris, —as well as the free inosculation between the carotids and vertebrals by the basilar, are modifications in the distribution of arteries, which serve the essential purpose of preventing any interruption to the necessary supply of blood to the respective organs. For a similar purpose, some important organs are supplied with vessels from *several* trunks,—as the brain, with its two

vertebral and two carotid arteries,—the stomach, with its different vessels, and the eye, with branches both from the internal and external carotids.

The office either of *diminishing* or of *increasing* the quantity of blood in certain parts of the body at particular times, is a function of the circulation not depending altogether on the heart, but requiring the cooperation of the vascular system. When, for instance, food is taken into the stomach, its vessels become more replete with blood, which additional quantity is derived from the vessels of the spleen, that organ serving the purpose of a receptaculum.—When the intellectual powers are excited, an additional quantity of blood flows into the brain, and so with regard to the erectile tissues of the corpora cavernosa as well as the vessels of the uterus, and testes, whenever these organs are called on to perform their particular functions.

In like manner we shall find that the heart itself requires a different quantity of blood in its varied conditions, and it becomes an interesting subject of enquiry to discover how that supply of the sanguineous fluid to the heart is always furnished with the requisite regularity; a function which I shall endeavour to shew is performed by the muscles.

The Musculo-Cardiac Function.

However difficult it may hitherto have been to explain the phenomena of living bodies, yet, whenever we have gained a step in physiological science, we are struck with the remarkable simplicity in the means which nature employs for accomplishing what had to us appeared a most complicated function in the animal economy. In endeavouring, therefore, to explain any of those phenomena of living beings which have hitherto evaded research, it may be anticipated, that, if such inquiries be successful, they will not lead to the discovery of *new laws*, but unfold the same simplicity of means for performing those operations of the economy, which have already been disclosed by human intellect. It has been indeed justly observed, in allusion to the progress of chemical science, that it has shown "from what a small store of primitive materials have all that we behold and wonder at been created!" And in like manner we perceive that as physiology has advanced and we have been able to explain any of the phenomena of living animals, the laws which govern them are found to be equally few and simple; so that it is by no means improbable that some such general law as that of *gravitation*, which governs the

Chenevix.

material world, will be discovered to govern and regulate all the phenomena of organized beings.

Some organs perform several functions.

In the arrangements of the animal economy it may be frequently observed that one organ is destined to perform several distinct functions—functions indeed so dissimilar and apparently so unconnected with one another, that it would not be anticipated they could be executed by the same physical apparatus.

As those of mastication.

Thus, for example, the muscles of the jaw are not only employed to masticate the food, but they at the same time evacuate the salivary glands and squeeze the saliva into the mouth by the pressure which they produce during their contractions on the salivary apparatus. The urinary organs of the male, moreover, are employed for the transmission of the seminal fluid, as well as to afford a passage for the urine. And the bones not only support the body like a framework, but they afford fixed points for the origin and insertion of the various muscles, and also form walls of defence for the internal organs, as the brain and the thoracic and pelvic viscera.

And those of Urine.

And the Bones.

And the organs of Respiration.

The functions of the respiratory apparatus are still more multiplied. Besides arterializing the blood,—conveying odorous substances through the nasal passages to the organ of smell,—assisting the return of the venous and expelling the

systemic blood,—and producing the voice; they also, as I shall subsequently endeavour to demonstrate, are employed in modifying the supply of blood to the heart. In birds we find that the functions of the respiratory apparatus are even more numerous, the air passing into membranous sacs within the chest and abdomen, as well as into their hollow bones, in order to assist their flight.

And the Muscles.

In like manner we shall find that the *muscles*, besides being the active organs of motion, destined to perform the various movements of the body, are essential auxiliaries in the circulation of the blood, in the arteries as well as in the veins, performing these offices merely by the pressure which they produce during their contractions on the adjacent vessels.

A general view of the means by which the circulation of the blood is carried on throughout the animal creation, as well as the phenomena of diseases, points out the errors of those physiologists who have endeavoured to explain the *systemic* circulation by the action of the heart alone. The momentary flushings of the cheek, and the diseased changes in the cutaneous *capillaries* of a common pustule might surely have been deemed sufficient to show that those vessels

are endowed with powers and perform functions in the circulation which are independent of the central organ.

Grant's Lectures on Comparative Anatomy, Lancet, Vol.

The fact that the circulation of the blood is carried on in some of the lower animals, as in worms and in insects, without a heart, and only by the almost incessant motions of their bodies, might have indicated that muscular contractions have at least *some* influence on the circulation of the blood in the arteries as well as in the veins.

So important indeed is the influence which the muscular movements have on the circulation of the systemic blood, that in various tribes of animals, the heart is found developed more and more perfectly in proportion as the body is less exposed to motion. Whilst, therefore, the restless *insect* requires no heart to impel its blood, the *shell-fish*, fixed and motionless on its rock, is provided with a central organ or heart, to carry on the circulation. In man the duty required of the heart must therefore vary with his bodily pursuits, the sedentary habits of some causing this organ to derive little or no assistance from those of locomotion, whilst the active occupation of others will materially aid the circulation of the blood.

When the respiratory apparatus is healthy, and the circulation through the right heart undisturbed, the pulmonary veins afford a sufficient supply of arterialised blood to the left heart for the ordinary purposes of the systemic circulation. During sleep this must be strictly true, but when the heart is suddenly required to act with unusual vigour, a circumstance which is constantly taking place whilst we are awake, an increased supply of blood then becomes necessary, the energy of the heart depending on the quantity of blood with which it is supplied. This important office we shall find is fulfilled, not only by *accelerating* the flow of the venous blood into the right heart, but, as I shall endeavour to show, also by *impeding* the exit of the arterial blood from the left heart, and both these purposes are admirably effected simply by the change of form which the muscles undergo during their contractions.

Muscles accelerate the return of the venous blood.

That the velocity of the circulation in the veins of the extremities is accelerated by the contraction of the muscles of the limbs, and consequently that muscular exertions assist in propelling the venous blood towards the right heart, is a fact long since pointed out and generally admitted by physiologists. It was consi-

See Appendix E.

dered by HALLER, and has never been contradicted by subsequent writers,—as alone sufficient to explain both the increase in the heart's action and the frequency of respiration which follow muscular exertions.

And impede the exit of the arterial blood.

But whilst the pressure caused by muscles during their contraction propels the blood onwards in the contiguous *veins*, it seems never to have been contemplated what must be the effect of that compression on the adjacent *arteries*, although these vessels are doubtless alike exposed to its influence. It will however be shown that the effect of muscular contractions both on arteries adjacent to, as well as on those imbedded in, the substance of muscles, must be to compress these vessels, by which compression the flow of blood through them will be necessarily impeded, —hence, the contraction of muscles will increase the accumulation of blood within the heart in two ways,—by *accelerating* the flow of the venous blood to the right heart, and by *impeding* the transit of the arterial blood from the left heart.

See Appendix F.

Mr. Hyslop having bled a lady to syncope, became alarmed at its long continuance, and on accidentally raising her from a horizontal position by grasping her arms and supporting by them the weight of the body, she rapidly

recovered. Surprised at this, more particularly as the change from the horizontal to the erect posture might have been expected to have had an opposite effect, Mr. H. was led to reflect what could be the cause of so sudden a restoration of the heart's action, and he became convinced that whilst elevating the body and allowing its weight to be supported on that part of the arms along which the brachial arteries pass, he must have compressed those vessels, the effect of which compression was an impediment to the flow of blood through these arteries, and consequently an increase in the quantity of blood in the heart. He thence concluded that the rapid recovery of this patient from syncope was analagous to the artificial process of transfusing blood. Subsequent experiments enabled him to prove the accuracy of his observations. He found that by the application of a tourniquet on the brachial artery he could increase the heart's action about ten pulsations in five minutes; an ingenious mode which he proposed to adopt in cases of syncope or apparent drowning in order to revive the heart.

Effects of a Tourniquet.

This interesting observation, as I shall endeavour to show, leads not only to a satisfactory explanation of some phenomena of the circulation, but in particular it explains how the quantity of

arterial blood, and, consequently, the vigour of the heart's action, are increased by muscular exertions.

The muscles employed to compress arteries.

The effect of muscular contractions in compressing arteries and consequently in impeding the circulation of the blood through them, may be demonstrated by experiment as well as by an examination of various phenomena.

Proved by experiment.

If the radial artery of a person who is powerfully contracting the muscles of the arm be examined, its pulsations are soon found to become feeble, and, at last, they are scarcely perceptible; whilst the moment the muscles are relaxed the artery is perceived to beat with its natural force. By the same experiment it may also be shown, that the effect of impeding the transit of the blood in the arteries is to increase the action of the heart, it being found that, in proportion as the strength of the pulsations of the radial artery diminishes, so is the impulse of the heart increased.

Position of arteries in relation to muscles.

Next let us consider the position of arteries in their relation to the muscles and learn the mechanism which enables the muscles, on contracting, to compress the contiguous blood-vessels in such a manner as to *impede* the systemic circulation.

For performing this important function, and

which I have denominated the *musculo-cardiac function,* we perceive several simple and beautiful contrivances; whilst we also find a striking illustration of this peculiar office of the muscular system in the mechanism which nature has adopted in order to *prevent* the compression of some arteries, when such compression would be injurious to the proper performance of the functions of those organs which such arteries supply. For although it appears that it is not requisite that some organs should be at all times supplied with an equal quantity of blood, there are others wherein any alteration in the supply of blood, would be prejudicial, or even fatal, to the great functions of life; and hence whenever the heart requires an additional quantity of blood, that office is fulfilled by impeding the flow of the arterial blood through the arteries of those organs only which do not at all times require a uniform supply of the sanguineous fluid.

Some arteries exposed to, and some protected from, pressure.

In accordance with these positions, we find that the arteries of all organs of the first denominations are so placed that they must inevitably be more or less compressed by the contractions of the adjacent muscles; whilst the arteries of the other class of organs are so situated, that they are protected from all pressure from

the movements of the muscles contiguous to them.

For a demonstration of the first of these conditions, we must look at the arteries of the limbs, while those of the brain, heart, stomach, and iris, each exemplify particular contrivances, by means of which the quantity of blood in these organs is not subject to any variations from muscular movements.

There are, indeed, several points, in the anatomy both of the muscles and of the arteries, which seem to be specially subservient to the musculo-cardiac function. Arteries accompany the veins where it is intended that *both* these systems of vessels shall be influenced by muscular contractions; yet, long as the period has been that the relative position of the blood-vessels and muscles of the limbs has been pointed out, no rational explanation of the utility of such an arrangement has been given. It is, however, evident, according to the preceding views, that, by such a disposition of the two systems of vessels, the velocity of the blood is equally influenced in the veins and in the arteries whenever the adjacent muscles are contracted; —that whilst muscular contractions assist in propelling the blood in the veins forwards to

Why veins accompany some arteries.

Muscles compress both.

the right heart, the valves preventing its regurgitation, the same pressure impedes the current in the contiguous arteries, and thus diminishes the exit of blood from the left heart.

Here, then, we have an anatomical fact, affording additional proof of the simplicity and wisdom which nature displays in all her works, employing one organ to perform at the same time more than one function,—veins and arteries accompanying each other in those situations where it is intended that the circulation of the blood, both venous and arterial, shall be influenced by the contractions of muscles; at the same time those vessels which are *not* liable to compression from muscular contractions are not similarly disposed, either with relation to the muscles or to each other;—thus in the internal viscera, such as in the brain, lungs, and liver, the veins do not accompany the arteries.

Besides this ingenious contrivance to enable the muscles to assist in accelerating the return of the venous blood to the right heart, and to impede the exit of the arterial blood from the left heart, we find that the relative position of the blood-vessels and muscles to one another is such, that whenever muscles are thrown into action they necessarily cause the adjacent blood-vessels to be more or less compressed, the heart,

under such circumstances, requiring additional vigour.

No arrangement could be better adapted for such compression than the course which is allotted to the femoral and brachial arteries, these being in some places completely encircled and embedded in the large muscles of the extremities, so that on every movement of the limbs they must suffer compression, and the current of the systemic blood be thereby more or less impeded.

How some arteries are protected from muscular compression.

Whilst it is interesting to examine Nature's contrivances in order to *impede* the flow of blood through the arteries, when she requires to increase the quantity of the sanguineous fluid in the heart, it is no less instructive to observe the means which are employed to *prevent* muscles from compressing the arteries and veins of certain organs any interruption in the supply of blood to which would be injurious.

In those arrangements where such compression from the muscles is to be avoided, we either find circles of *anastamosis* established between different arterial trunks, or the vessels are so placed that they are completely protected from all that pressure which would be produced by the contractions of the adjacent muscles.

Of the first of these provisions we have ex-

amples in the coronary arteries of the stomach and lips, and in the circles of anastamosis of the arteries of the iris,—the effect of all which free inosculations is obviously to render any obstruction in the arterial circulation in these organs impossible, a circumstance which would be constantly taking place from their unceasing movements, had not such anastamosis been established.

Coronary arteries of the heart.

The other provision is exemplified in the heart and in the brain. In order to prevent any interruption to the circulation in the vessels of the heart, there is not only a free anastamosis between both coronary arteries, but also a peculiarity of structure to which I have alluded, —those vessels passing along a tendinous furrow or groove between the auricles and ventricles in such a manner that, during the unceasing contractions and relaxations of these cavities, the circulation of the blood, neither through the veins nor arteries, can be in any way interrupted.

The vertebra arteries.

And again, if we look at the brain, we observe that its vessels are also protected from all muscular compression, independent of having a free anastamosis established between them. The vertebral arteries pass along a bony canal, where they are so protected that the current of the

blood in them can never, like that in the carotids, be interrupted by the contractions of the muscles of the neck during the very frequent and varied positions of the head; whilst the anastamosis established between the carotids and vertebral arteries secures a constant supply of blood in all the arterial ramifications within the head.

The circulation within the head.

This mode of securing that regular supply of blood to the brain, as well as to the substance of the heart, indispensable for the due performances of their functions, is indeed a striking example of the consummate skill and simplicity always evolved whenever we succeed in unfolding Nature's works. The passage of the two vertebral arteries in such a situation as not to be susceptible of compression by the contractions of the cervical muscles enables those vessels under all circumstances to supply the brain with an uninterrupted stream of blood, whilst any irregularities in the supply of blood to the branches of the internal carotid arteries are also amply provided against by the free communication of these vessels with the two vertebral arteries by means of the basilar artery,—so that by this simple mechanism the branches of the carotids are as well supplied with blood as those of the vertebral arteries.

Its supply of blood uniform.

If such a distribution of the arteries of the brain did not exist, and if the vertebral arteries, like the carotids, were constantly exposed to compression from the contractions of the muscles of the neck, and from alterations in the position of the head, or if there were no free communication between the vertebrals and carotids, then the quantity of arterial blood within the head would be exposed to constant variations, and the functions of the brain would be liable to incessant disturbance,—accidents which the mechanism I have now described is, however, ingeniously calculated to avert.

Its venous circulation.

But an equal and uninterrupted return of the *venous* blood from the head is of no less importance in the due performance of the brain's functions than a regular supply of *arterial* blood; hence the importance of that peculiar structure,—the unyielding parietes of the veins or sinuses, for warding off the effects of that very compression which is provided in some other veins for the purpose of *accelerating* the return of the venous blood.

The circumstance of the cerebral arteries being distributed and protected in such a manner as always to ensure a regular supply of blood to the brain may, perhaps, along with the peculiar structure of the veins, be considered as the cause

of this organ suffering more than most others when the heart is diseased, a circumstance, which I shall subsequently have occasion fully to explain.

From what has been said, it is evident that, except in a few organs, the supply of blood must be more or less irregular, their varied functions not requiring the same nicety in the regulation of their supply, and when, the heart's action is disturbed, any temporary irregularity in the distribution of the blood to these organs is not therefore injurious. With the brain, however, it is essentially different; and the mechanism by which the sensorium is provided with a regular supply of blood becomes, as I have already remarked, the very means of rendering it more liable to derangement whenever the function of the heart is disturbed. On such grounds I shall endeavour to account for the unnatural sounds, false images, vertigo, inability to balance the body, and various disturbances in the cerebral functions, which so frequently, nay, almost invariably, accompany diseases of the heart.

Influence of the involuntary muscles on the circulation.

The effects which I have described of the contractions of the muscles of the extremities in compressing the brachial and femoral arteries will suffice to point out what is here requisite to

be noticed as regards the influence of the *voluntary* muscles in increasing the vigour of the heart; but we also find that the *involuntary* muscles perform an equally important share in modifying the circulation of the blood.

I have already shown that the arteries which supply the heart, and likewise those of the stomach, lips, and iris, are each so situated that the circulation in them can never be interrupted by the movements of these organs. Neither are the arteries of the brain nor those of the lungs, subject to pressure from the contractions of the voluntary or of the involuntary muscles, the anastamosis and the protection which is afforded to the cerebral arteries warding off the influence of any movements of the neck; and the pulmonary vessels are affected only indirectly by the movements of the parietes of the chest.

But when we examine the alimentary canal, we there find an illustration of the function performed by the contraction of the *involuntary* muscles on the blood's circulation. The vermicular motions of the stomach and intestines during the process of digestion must doubtless have a very considerable influence on the circulation of the blood, both in the veins and in the arteries of these organs, and hence,

Influence of the peristaltic motion of the alimentary canal on the circulation.

during the movements of the alimentary canal, we observe an increase in the impulse of the heart, indicated by an increase in the frequency of the pulse. In this respect, the circulation of the blood in the intestinal canal in part resembles that which exists in *worms,* the almost unceasing movements of these animals being sufficient, as I have before noticed, to circulate their blood, unaided by a heart.

The Musculo-Cardiac function explains various phenomena.

In the next place I shall proceed to show, that the Musculo-Cardiac function enables us to explain many important phenomena which are constantly occurring in the living body, and which could never have been explained, until a knowledge of this function of the muscles had been discovered.

Some muscular movement will be observed to precede every effort which we make to increase the action of particular organs, because, for such a purpose, it is first required that the vigour of the heart shall be increased. Hence we find that, unless when the body is in a state of perfect tranquillity, which can scarcely ever happen but during sleep, the circulation of the blood throughout the system is constantly varying, any muscular movement, however slight, increasing the influx of the venous blood, and at the same time impeding the reflux of the arterial blood. Thus

in some organs the quantity of blood is diminished, and in others increased, by every motion of the body, those which are called upon to perform particular functions receiving an increase, whilst other organs whose office is less urgent, experience a diminution in the supply of the sanguineous fluid.

It is, indeed, interesting to contemplate the contrivances which are employed in order to fulfil this office in the various organs, and to observe the injurious effects which result from deviations in the due execution of this function of the circulating apparatus. No more satisfactory illustration can be indeed given of the office of the muscles in modifying the circulation of the blood, or of the Musculo-Cardiac function, than by glancing over the developement of those phenomena which may be observed in a living being, at the moment of awaking from sleep, and by reviewing the various functions successively as they are evolved.

Awaking from sleep.

The first indication of a person passing from sleep into a state of watchfulness, is *some movement of the body.* He changes the posture in which he has been slumbering; the limbs begin to move, and, almost at the same moment, and just when he is becoming conscious of existence, the muscles of the extremities are thrown into

contraction; he stretches the limbs and yawns, and, finally, the intellectual powers awake!

These phenomena are so uniform, though they may vary in degree, and so universal throughout the animal creation, that it would be unphilosophical to suppose they were not a link of some chain, which, however inexplicable, could not reasonably be supposed to be the result of chance, or the effect of habit.

Phenomena accompanying it, how explained.

All these muscular movements can, indeed, be satisfactorily explained by contemplating the effects on the circulation, which as I have endeavoured to demonstrate, are produced by muscular contractions.

See Appendix G.

The almost instantaneous effect of a person stretching the limbs whilst awaking from slumber, is that of rousing the powers of the mind, and this arises from an accumulation of blood in the heart, which such motions necessarily create, and which, by increasing its action, enables it to propel an additional quantity to the head.

Scarcely has a man awoke, and the brain received this additional quantity of blood, ere the mental powers are resuscitated, and having been refreshed by "balmy sleep," they almost immediately resume their wonted vigour!

The powers of the mind having revived, man is

now befitted for his varied avocations, in the execution of which the Musculo-Cardiac function continues to perform an important share.

Phenomena which precede exertions explained.

Observe how the strength and vigour of the body is increased when we require to make any great exertion! In order to produce a temporary increase in the heart's action, I have already remarked that it is requisite to give to that organ an additional stimulus. This is at once effected by throwing into action such muscles as shall, by their newly acquired forms, compress the contiguous arteries, and thus impede the transit of the arterial blood.

Those made before running or leaping;

If, by way of illustration, a man be about to make any great exertion, such as running or leaping, he prepares himself, as it were, by first vigorously contracting the muscles of the arms and clenching his hands.

in preparing to endure pain;

For the same reason, when a person is subjected to pain, as that of a surgical operation, he prepares himself to endure it by throwing into action almost all the voluntary muscles, grasping firmly with his hands, and pressing the feet against some resisting body.

and in the female during parturition;

And when the female, during parturition, is about to make a powerful expulsive effort to assist the uterus in giving birth to the infant, she in like manner throws into violent and long continued contractions the muscles of the extremities,

clenches the jaws, and squeezes with a convulsive effort whatever may be within her reach.

and in disease;

Muscular exertions are also employed to effect a similar purpose in those who, from disease in the urinary passages or rectum, have great difficulty in voiding their contents; so that, before endeavouring to accomplish such evacuations, they forcibly contract some of the voluntary muscles,—muscles whose actions are totally unconnected with those which are employed to perform the evacuations.

and in recovering from syncope.

No less remarkable is the influence of this function of the muscular system on a person who is recovering from a state of *syncope*. Having passed into a condition where the last spark of life had been apparently extinguished, the first symptoms of recovery from fainting are ushered in by a series of convulsive movements of the voluntary muscles. Long protracted inspirations are succeeded by powerful expirations; the limbs are convulsed, and soon afterwards the intellectual powers are resuscitated.

The effects of bodily exercise, how explained.

The influence of muscular contractions in increasing the vigour of the heart also explains, in a very satisfactory manner, the salutary effects which children derive from their almost constant movements, and the benefits which arise from all kinds of bodily exercise. How a person,

when he feels sluggish and inert after mental fatigue, or from want of sufficient bodily excitement, is revived and invigorated by walking; it also accounts for the exhilarating influence of dancing, or driving rapidly in a carriage, and fully explains the "intoxicating effects" which, according to the poet, the Arab experiences while galloping across the boundless desert!

On the Orator this influence of muscular movements is no less striking. His gestures keep pace with his mental excitement, and the gesticulations become more and more extravagant in proportion as he becomes impassioned; the heart thus acquiring an increase in the quantity of its blood, and, consequently, the brain receiving a proportionate increased supply.

All these phenomena can be explained now that we comprehend how muscles during their contraction increase the quantity of arterial blood in the heart; and it is only surprising that physiologists, when endeavouring to account for the beneficial influence of various exercises, and having shown that they increase the return of the *venous* blood to the central organ of the circulation, should not have advanced a step further and considered, what must be the effect of muscular contractions on the adjacent *arteries*.

See Appendix H.

Influence of the Musculo-Cardiac Function in diseases.

My attention was directed to some of these phenomena and to the physical explanation of them which I have now given, when attending a patient who had frequent attacks of gout, and who had been sometime before affected with an arthritic inflammation of the pericardium. After that illness he suffered from palpitations of the heart every morning just at the moment when he awoke, but they continued only a few minutes. On enquiring if he was in the habit of yawning and stretching his limbs, he then stated that he always did so whilst in the act of awaking, and that it was immediately afterwards when he felt the palpitation. He further observed, when interrogated on this point, that, if he accidentally awoke during the night and stretched himself, palpitation of the heart always ensued.

The effect of yawning and stretching the body in disturbing a diseased heart I also observed in a person who had for many years suffered from symptoms of Hypertrophy, and who was recovering from a febrile illness, for the relief of which an antiphlogistic treatment had been pursued. When convalescent, this patient had no uneasy feelings remaining except a pain in his head, which came on every morning immediately after he awoke, but did not continue longer than ten

minutes. From the circumstance of this headache occurring only after he awoke, and from his stating that he was in the habit of yawning and forcibly stretching his limbs whilst he was awaking, it appeared to me probable that the increase of blood in the irritable heart caused by those movements, produced the *headache* in the same manner as it had in the former instance caused *palpitation.*

The influence of the Musculo-Cardiac Function explains how there is such a remarkable difference in the number, as well as in the strength, of the heart's pulsations when the body happens to be in the recumbent or in the erect postures,—a difference particularly striking in all invalids, and which must have led to the advice so commonly urged, of preserving bodily tranquillity in the treatment of diseases. The difference in the pulse is indeed sometimes so considerable in the different positions of the body that it is usually necessary, before being able to form a correct judgment of the state of the circulating system, to examine both the heart and pulse when the patient is in the recumbent as well as when he is in the erect posture.

Many of their symptoms accounted for.

If therefore the influence of muscular contraction on the *arterial* circulation be admitted, it not only enables us to give a rational explana-

tion of many phenomena which take place in the healthy state of the body, but it opens a most important field for the researches of pathologists. It explains the hurtful effects of severe bodily exertions in over exciting the heart. It explains also the beneficial influence of bodily tranquillity in all those ailments wherein the circulation is hurried or disturbed. It accounts for the great frequency of some diseases of the heart in two very opposite classes of persons,—in those whose avocations expose them to violent muscular efforts, and in those whose organs of circulation, in consequence of taking little exercise, obtain little or no assistance from the musculo-cardiac function.

And their frequency in particular classes of individuals.

The various involuntary movements which occur in some diseases, such as those during convulsive, epileptic, and hysterical fits,—the permanent muscular contractions in those afflicted with trismus, and the temporary movements in chorea, must all have a greater or less influence on the action of the heart, and can only be explained by a reference to the musculo-cardiac function.

In like manner we can account for those differences so remarkable in the vascular system of the two sexes. As the circulation of the blood in the female, in consequence of her

And the difference in the vascular system in the two sexes.

inactive habits, derives little assistance from muscular contractions, the arteries consequently become more lax and capacious than those in the male; whilst the veins of the male are proportionably much larger than those of the female, the venous circulation being greatly influenced by all those muscular exertions to which men are so much exposed. In proof of these differences in the vascular system of the two sexes, it is only necessary to compare the distended and tortuous veins of an artizan with the delicacy and beauty of the surface of the female.

Position of arteries in animals to avoid compression.

Before concluding this part of the subject, I may notice, as a further proof of the effect of muscles compressing arteries during their contractions, an ingenious mechanism in some animals, which is calculated to guard against compression where such pressure would be injurious. In those of the feline tribe, and which use their paws not only for climbing, but for grasping their prey, in order to prevent the pressure which is unavoidably made on the limbs from impeding the flow of blood through the brachial arteries, these vessels pass through a bony canal formed in the humerus at that part where they would be most liable to compression, and thus the circu-

lation of the blood goes on without interruption, though these animals continue even many hours, firmly grasping their prey. In the lion also a provision is found in the distribution of the arteries of the head so that the muscles of the jaw can be kept for a long time in a state of powerful contraction without the circulation being interrupted.

For a like purpose a peculiarity is found in the trajet of the aorta in some fishes. After having supplied the abdominal viscera that vessel in the shark passes along a channel formed by the bony processes of the vertebræ, so that the circulation can never be disturbed in the powerfully muscular tail, during any of its movements.

Here, then, as well as in the brain and heart, is an example of arteries passing along a course by which they are protected from muscular pressure, whilst we have found other vessels so placed that they are subjected to muscular compression in order to fulfil a very important function in the animal œconomy.

The Respiratory Organs.

Having noticed the power of the heart in propelling the blood,—the different modes by which the arteries regulate its distribution to the various organs,—the changes produced in the circulation

by the action of the capillaries,—and having pointed out how the supply of blood, both to the right and left heart, is modified by the contractions of the muscles, we come next to consider the influence which the respiratory organs exercise on the function of the heart, and the share which they have in carrying on the great function of the circulation of the blood.

Influence of Inspiration on the Circulation.

By whatever powers the venous blood reaches the two venæ cavæ, *inspiration*, or that movement which draws the air into the chest, assists in bringing the *venous* blood into the right heart. Inspiration also assists the circulation of the blood in the pulmonary arteries, the expansion of the lungs accelerating the ingress of the venous blood into the pulmonary arteries, and also permitting the arterialised blood to flow readily through the pulmonary veins.

Influence of Expiration.

Whilst the entrance both of the air and of the venous blood into the chest takes place during inspiration, so in like manner is the air expelled and an impulse given to the systemic blood during *expiration*. The collapse of the lungs and the subsidence of the parietes of the chest and abdomen which take place during expiration, aid by their pressure the transmission of the arterial blood from the lungs into the left heart, and also assist in propelling the blood

Haller's first lines of Physiology.

along the large arteries, at the same time impeding the current of blood coming from the right ventricle into the pulmonary artery.

Inspiration may be therefore considered as accessory to the *venous* and expiration to the *arterial* circulation, the one aiding the heart like a sucking and the other like a forcing pump.

Reciprocal influence of Respiration and Circulation.

Hence the reciprocal influence or cooperation which is to be observed in the two great functions of animal life, and how we are enabled to explain the use of various peculiarities in the structure of both the respiratory and circulating apparatus which are found in the different tribes of animals,—all of which I shall endeavour to show are intended to modify and regulate the distribution of the blood throughout the system, according to the necessities and habits of the different races of organized beings.

Uses of their various modifications.

To effect a variety of purposes in the animal œconomy, we find that modifications in the inspirations and expirations are constantly resorted to, sometimes the inspirations and sometimes the expirations being either lengthened or shortened, by which modifications changes are produced in the quantity of blood within the heart. The aspirations are changed in the act of swinging—turning round rapidly—standing on

the head—or when a person is on board of ship. Respiration is also modified in sobbing—sighing—yawning—laughing—and in vomiting and hiccup,—all which acts I shall subsequently endeavour to show are resorted to by the system for the purpose of restoring or adjusting a circulation which had been disturbed.

How the Heart's action is changed by Respiration.

Such indeed is the influence of respiration on the action of the heart, that its movements can be even altered by a voluntary change in breathing, and experiments have shown that when an animal is decapitated and the heart has ceased to beat, its action may be restored by artificial breathing. Thus some persons can by making a very slow and long protracted inspiration render the action of the heart so languid that the pulse cannot be perceived at the wrist, and in like manner by a very quick breathing the action of the heart can be greatly accelerated.

Case of Fontana.

It is said of Fontana that he acquired such command over the action of his heart, that he could accelerate or retard his pulse at pleasure ; which must have led to the opinion that the heart itself is in such cases immediately under the influence of the will.

Dr. Cheyne's "English Malady."

The remarkable case of Colonel Townsend has been frequently referred to in order to show the influence of the mind on the action of the

heart, though the power which he possessed over it was evidently affected by changes produced in respiration. It is said that a few days before his death he could expire when he pleased, and by an effort he could come to life again! Before making the experiment on the day of his death his pulse was distinct, though small and thready, and his heart had the usual beating. He composed himself and lay on his back in a still posture for some time. His pulse sunk gradually, till at last it could not be felt by the nicest touch; not the least motion could be felt in the heart, *nor the least soil of breath perceived on a bright mirror held to his mouth;* not the least symptom of life could be perceived. He continued thus for half an hour, the motion of the heart was then observed gradually to return, and he recovered again, executed some business and died the same evening!

Singular case of a Lady.

This influence of the respiratory organs on the action of the heart was strikingly illustrated in the case of a lady whose heart sometimes acted so irregularly that she was apt to fall into a state of syncope. She accidentally discovered that by the act of *singing* she could prevent herself from fainting. "I will write you," she observed, "something very remarkable about myself, namely, that when my heart

is in a great flutter, and I am not certain whether I shall faint away, singing removes it almost directly. One Sunday, in church, I expected every moment I should be obliged to be taken out, and disturb the congregation, when happily the psalms were beginning to be sung, and I instantly joined in the psalm, and the comfort the act of singing then gave me was almost instantaneous."

Respiration is both Voluntary and Involuntary.

The muscles which are employed in respiration may therefore be considered both as voluntary and involuntary. During sleep, when the body is perfectly tranquil the respiratory movements are quite involuntary, but whenever the number or duration either of the inspirations or of the expirations is altered these changes are either involuntary or they may be made in obedience to the will. We consequently find that the nerves which supply the respiratory organs are ramifications of both classes of nervous trunks.

The Pulmo-Cardiac Function.

Besides these two important offices of the respiratory apparatus connected with the circulation of the blood, both of which may be considered as altogether depending on changes in the form and capacity of the thoracic cavities,

there is a third and I shall endeavour to show accessory function which is performed by the lungs themselves, the pulmonary vessels serving as a receptaculum or reservoir for receiving any surplus quantity of blood whether venous or arterial which the cavities of the heart cannot admit. Hence, in order to distinguish this function from all the others performed by the respiratory Apparatus I have denominated it the PULMO-CARDIAC FUNCTION.

As the supply of blood to the heart can scarcely ever be uniform, unless perhaps during sleep, the return of the venous blood and the exit of the arterial blood being subject to constant irregularities it is surprising that physiologists should never have enquired, by what means can the central organ of the circulation accommodate itself to such variations in its supply of blood.

The Pulmo-Cardiac Function.

Whenever from any cause the systemic blood cannot find a ready exit from the left ventricle, and when at the same moment there is no diminution in the supply of venous blood to the right heart, an accumulation or congestion of blood must then take place within the cavities of the heart, and therefore in order to prevent such undue accumulation the effects of which would be more or less injurious, further means become

requisite besides the expansive powers of the parietes of the chest.

Regulates the quantity of Blood within the heart.

This condition of the heart is constantly taking place, for as I have already said unless when the body is in a state of perfect tranquillity and all its functions undisturbed, the return of the venous and the exit of the arterial blood from the heart are subject to constant changes. Every muscular movement, the state of the stomach, the exercise of the mind, the varied position of the body, all influence directly or indirectly both the influx and the reflux of the heart's blood.

Importance of such a Function.

It is therefore important to discover by what means the heart can accommodate itself to such constant changes in the supply of blood, and how it can prevent those disturbances in the circulation which would be necessarily produced by irregularities in its supply to the different organs. This investigation we shall find displays a beautiful yet simple contrivance for executing what may have appeared a complex function of the œconomy.

The heart's own powers insufficient.

If there be only a slight increase in the quantity of blood within the heart, such additional stimulus by increasing the vigour of the heart's movements may, along with the elastic quality of the fibro-cartilaginous portion of its structure, which is

placed at the roots of the large vessels, be alone sufficient to equalize the circulation. But if the increased supply of blood to the heart be so considerable that the surplus quantity cannot be received within its cavities, the lungs are then required to lend their assistance.

Assistance derived from the Lungs.

To fulfil this *Pulmo-Cardiac Function*, the structure of the lungs is admirably adapted. The pulmonary vessels, being imbedded in a soft and yielding substance, are susceptible of various degrees of distension, so that they readily give way for the reception of any surplus quantity, whether of venous or of arterial blood, and retain it until it can be received within the heart. The structure with which the lungs are endowed to enable the air-cells to accommodate themselves to those differences in the quantity of air which take place during respiration, also enables the pulmonary vessels in their turn to accommodate themselves for the reception of the various quantities of blood which may be impelled into them.

The Lungs adapted for this Function.

Its extensive utility.

A function is therefore performed by the respiratory organs which is quite unconnected either with arterialization of the blood, with aiding the return of the venous blood to the right Heart, or with assisting the circulation in the pulmonary vessels, and when it is considered how

This Function not connected with the Arterialization of the Blood.

often and by what slight causes the current of the arterial blood is impeded in leaving the left heart, and how frequently the return of the venous blood is accelerated to the right heart, this Pulmo-Cardiac Function must be regarded as one of primary importance.

Its influence on respiration.

It exercises, as might be expected, a remarkable influence on the function of respiration, for whenever the egress of the blood from the left heart is impeded by muscular contractions, and the exit of the systemic blood from the lungs into the left auricle is interrupted, the velocity of the blood in the veins will also be increased, and venous blood congested in the pulmonary arteries. Thus the blood being accumulated in the pulmonary arteries and veins, as well as in both hearts, respiration becomes quickened, and its frequency increased in proportion to the degree of impediment which is offered to the distension of the air cells; — and the respiration will continue quickened until the circulation be equalised, the heart become tranquil, and the congested lungs relieved of all surplus quantity of blood.

Accordingly it will be found that, unless when the supply of blood to the heart is uniform, respiration is constantly varying; sometimes the inspirations, and sometimes the expirations are

shortened or prolonged, or the duration of the interval between them is changed; all such variations being caused by alterations in the quantity of blood which is contained in the pulmonary vessels.

Assistance which it derives from the Veins.

But whilst the Pulmo-Cardiac Function is employed to relieve the heart of any surplus quantity of blood which it cannot receive within its cavities, the *veins* will in like manner be found to relieve the pulmonary vessels of any superabundant blood which they are not capable of receiving without interruption to the great function of respiration. This important office of the veins I shall endeavour to demonstrate by pointing out some facts regarding the structure of the venous system, and also by considering some phenomena of the circulation which are constantly taking place.

This office of the Venous system

When describing the effects of muscular contractions on the circulation, I endeavoured to show that certain classes of muscles are employed to compress by their contractions veins as well as arteries, and that both systems of vessels are so placed in relation to such muscles as to be compressed whenever the contiguous muscles are thrown into action. I also pointed out, that whilst one class of arteries were employed for performing this important office

in the circulation, there was another class which was not required to execute that function, and these arteries were so placed in relation to the muscles, that the contractions of the muscles could not influence the circulation of the blood.

is performed by the subcutaneous Veins.

The division of the arteries into those vessels which are, and those which are not influenced by muscular contractions, we shall also find applicable to the venous system, one class of veins being so situated that the circulation of their blood is affected by muscular movements, whilst another are never under the direct influence of the active organs of motion. The first class comprehends the deep seated or *intermuscular*, and the other consists of the superficial or *subcutaneous* veins. Hence in the limbs, the deep veins which are intermingled with the muscles are influenced by every muscular contraction whereas the subcutaneous or superficial veins, being placed externally to the fascia, are not affected by the action of the muscles of the extremities. Whilst therefore the chief function which the veins perform consists in the conveying the blood back to the heart, there are likewise other offices especially executed by each subdivision of the venous system.

By forming a Receptaculum.

That the subcutaneous veins perform the

office of a receptaculum, by receiving any surplus quantity of blood which cannot be admitted into the pulmonary vessels,—in like manner as we have seen that the pulmonary vessels themselves receive that blood which the cavities of the heart cannot admit,—is illustrated by observing the phenomena which accompany the different degrees of distension of these vessels.

This function of the veins demonstrated.

The most remarkable of those phenomena is what we have constantly opportunities of observing when the regularity of the circulation is disturbed by muscular exertions. If these are made within certain limits it has been already noticed that the pulmonary vessels are endowed with powers of extension sufficient to contain the additional quantity of venous blood propelled forwards to the right heart, and also of arterial blood impeded from leaving the left heart. But when the lungs become congested, and can no longer admit into their vessels any additional quantity of blood, not only is the systemic blood driven into those arteries which are not influenced by muscular compression, but we observe that the venous blood which cannot find access within the thoracic cavity stagnates and becomes accumulated in the subcutaneous veins. No more striking example can be given of this office of the superficial veins, than their distended

appearance beneath the delicate skin of a race-horse after a severe gallop.

Pulmo-Cardiac congestion.

But neither this accessory function of the subcutaneous veins, the increase in the heart's action, nor the aid which the respiratory organs afford, are always sufficient to prevent a permanent congestion of blood within the cavity of the chest; for whenever muscular exertion is carried to its extreme limits, the accumulation of blood both within the pulmonary vessels, and the cavities of the heart becomes such, that the balance of the circulating and respiratory apparatus is destroyed, the congestion renders them incapable of sufficiently evacuating themselves, and the accumulation in the vessels of the lungs prevents the inspiration of a sufficient quantity of air for arterializing the blood.

Its pernicious effects.

In this state of congestion it often happens that the pulmonary vessels give way, and a hemorrhage ensues which is sometimes fatal,—or death may be caused by suffocation. In animals which have died in the act of making a violent muscular exertion, it has also been found that life was not extinguished from the bursting of any of the heart's cavities as some have supposed, but from their being so much overdistended with blood, as to destroy the heart's action, and likewise from the pulmonary vessels being so much

gorged as to prevent the ingress of the requisite quantity of air for the arterialization of the blood. This condition has been observed in horses that have died suddenly from severe galloping, and in some instances so violent had been the efforts to carry on respiration that the diaphragm has been found in these animals torn and permitting even portions of the abdominal viscera to pass into the cavity of the thorax.

A congested state of the thoracic viscera from violent exertions when not carried so far as to destroy life, may however go the length of producing such a derangement of the circulation as the respiratory and circulating organs combined have not the power to restore, and although by a system of "training," a power of adjusting these organs so as to carry on respiration during such exertions may be acquired to a surprising degree, yet if the Pulmo-Cardiac congestion goes beyond certain limits, a permanent disturbance of the circulation takes place, and the functions of respiration and circulation are never afterwards perfectly restored.

Accordingly we may observe an almost infinite variety in the period which is required to tranquillize the movements of the heart and lungs after they have been disturbed by any muscular exertion,—that period depending on the violence

of the effort as well as on the *condition,* as it is called, of the person by whom it has been made.

"Training" how explained;

These observations naturally lead us to enquire, what are the means by which a person attains the power of regulating the respiratory and circulating organs so as to be able to make violent muscular exertions, until his muscular energy is exhausted, or in what consists the art of training. This subject has never sufficiently claimed the attention of Physiologists, and no one as far as I know has contemplated what, or whether any changes take place in the physical condition of the thoracic viscera of those who have been trained to perform feats of strength.

Erroneous opinions concerning;

It has been usually considered that the only change produced on the system by training, has been an increase in the muscular fibre, but a careful investigation of the varied functions of respiration and circulation, along with some points in the anatomy of the respiratory apparatus will enable us to give a more satisfactory elucidation of the changes which take place, and will also lead to an explanation of several symptoms in the diseases of the thoracic viscera, which have hitherto evaded Pathological researches.

Its phenomena.

If we attentively examine the nature of train-

ing or "putting a person in wind," we shall find it consists in respiration being so regulated during muscular exertions that any pulmo-cardiac congestion is prevented, and this is effected by permitting the lungs to receive only such quantities of blood as shall not destroy the proper adjustment between the respiratory and circulating organs, whilst at the same time a quantity of air is inspired sufficient for the arterialization of the blood, and the muscular contractions are allowed to proceed until the energy of the muscles becomes exhausted. For, as I have already mentioned, if pulmo-cardiac congestion go beyond certain limits during any muscular exertion, the person becomes exhausted, not from the muscles being fatigued, but from the cavities of the heart and pulmonary vessels becoming so loaded with blood, as to interrupt respiration.

An important part of the anatomy of the lungs.

There is a circumstance regarding the anatomy of the lungs, described by Sir E. Home, which assists in explaining this peculiar feature in the function of the pulmonary apparatus.

Philosophical transactions 1827, Part 1.

From his observations it appears, that in proportion as the air cells are distended, the circulation of the blood in the pulmonary vessels is interrupted, and that if the cells be *completely* distended, the extreme ramifications of the

pulmonary arteries cannot transmit the blood to the pulmonary veins. When the arteries of a sheep's lungs were injected, the injection returned very readily by the veins, but when the air cells were previously distended, this did not take place, and the injection could not be forced into the pulmonary veins. See Appendix I.

Pernicious effects of too full Inspirations.

In further illustration of this important physiological observation I may remark that by very full inspirations the action of the heart is diminished, the shorter and the more frequent the inspirations the more rapid become the movements of the heart: and when from disease a portion of lung is no longer capable of assisting in the arterialization of the blood, that which remains sound having an additional duty to perform, respiration becomes increased in frequency. Respiration being quickened there must necessarily take place an increase in the heart's action,—and hence can be explained that quickness of the pulse which has been considered a pathognomonic of tubercular phthisis.

From the foregoing observations we are warranted in concluding that too full inspirations by over-distending the air cells and thus impeding the pulmonary circulation, will prevent the continuance of muscular exertion, whilst if the inspirations be limited so that the air cells

cannot be over distended, the free circulation through the pulmonary vessels will not be interrupted, and the muscles may continue to act until their energy is exhausted.

Training modifies the Respiration.

That training consists in acquiring a certain controul over the respiratory organs, and that one of its essential conditions is, that of limiting the *inspirations*, can be demonstrated by examining the mode in which respiration is performed by persons who are properly trained for athletic exercises.

The phenomena of Training illustrated;

It may be remarked, that those who are best trained require great care and nicety in order to adjust the respiratory organs.

in Dancers;

The trained dancer commences his performance by increasing the movements of his body in a very gradual manner, and an equilibrium is thus established between the respiratory and circulating organs, so that afterwards he can perform his greatest feats, and continue his exertions until his muscular energy is exhausted.

in Pugilists;

It is the same with the prize-fighter, for whom to retain his greatest physical powers, it is necessary that the muscular exertions which he is about to perform, be at first made only in a very moderate degree; for if, from passion, or too much excitement, he is induced to make a violent effort at the commencement, the necessary

adjustment in respiration is destroyed, and he cannot avoid failing in his enterprize.

In order still further to illustrate the necessary condition of the respiratory organs, for allowing the continuance of powerful muscular exertions, I may remark, that the various contrivances which are resorted to for effecting this purpose, all act by limiting the inspirations, and thus preventing such a degree of distension of the air cells as would impede the ready flow of the blood from the pulmonary arteries into the pulmonary veins.

in running a Race.

Hence in running a race it is found essential that the mouth be kept shut, a sufficient quantity of air entering by the nostrils for the arterialization of the blood, and experience having taught that if any additional quantity is inspired by the mouth, the proper balance between respiration and circulation is more or less destroyed, and the person obliged to discontinue the effort. The common practice, when running, of putting a pebble in the mouth, by the effort of retaining it, keeps the mouth closed. An animal at full speed it will also be observed, has the mouth always kept shut, either until his muscular powers begin to be exhausted, or when from alarm, he inspires by the mouth; so that whenever an animal which is pursued

opens its mouth, it is well known that he cannot long sustain his speed.

In like manner for limiting the inspirations not only does the man who runs a race keep his mouth shut, but he also places his arms close to his sides, with the fore-arms in a state of flexure, firmly contracting all the muscles.

And in raising a weight.

Artizans also whose avocations require a great muscular effort, are in the habit of tying a belt round the waist, thus preventing too great an expansion of the chest; and when the sailor prepares himself for battle, in order the more powerfully to exert himself at the guns, he ties a handkerchief firmly round the waist, by which during the excitement of the fight as well as the powerful muscular exertions which he is compelled to make, the movements of the respiratory apparatus are confined within certain limits, and he is prevented from making such full inspirations as would disturb the balance of the circulation within the chest.

The pernicious effects of violent exercise on the circulation, as well as the mode of avoiding them, are well understood by those who professedly train persons for gymnastic exercises, and it is by them considered a great nicety in the process of training, never to allow pulmo-cardiac congestion to be carried so far as to render the

thoracic viscera unable to remove without difficulty, whenever the muscular exertions which produce the congestion have ceased, all surplus blood from the pulmonary vessels. For when attention has not been paid to this circumstance, and when from an over-distension of the air cells the congestion has exceeded certain limits, an imperfection in breathing will continue, which in some instances prevents the person from following such exercises even throughout life.

The same may be observed in those who make any violent exertion to which they are not accustomed, and who continue ever afterwards to suffer from a disturbance in the thoracic circulation. The observations however, which I have to make on this subject, will be introduced more appropriately when we come to consider the pernicious effects of violent exercise on the respiratory and circulating apparatus.

Phenomena connected with respiration and circulation.

There are many important phenomena, as I have remarked, which will admit of a satisfactory explanation now that the connection between the functions of the heart, and respiratory apparatus has been pointed out,—phenomena which are constantly taking place, although the pur-

poses which they serve in the animal economy, have not hitherto been contemplated.

I shall endeavour to show that laughing,—crying,—weeping,—sobbing,—sighing,—vomiting,—coughing,—sneezing,—and hiccup,—are all acts which are resorted to in order to effect certain changes in the circulation of the blood in the lungs and heart, for some essential purpose. I shall also explain how certain sensations in the head, such as the giddiness felt from swinging,—turning round rapidly,—or from sudden alterations in the position of the body,—sounds in the ears,—images before the eyes,—sea-sickness,—are prevented in certain individuals by a power which they have acquired of modifying the function of respiration.

For each of these purposes, however, to which I have alluded, we shall find that only one of the offices of the respiratory apparatus is more especially employed. Thus full *inspirations* are made in order to relieve the head, because they accelerate the return of the venous blood to the right heart. Deep *expirations* will relieve the left heart of any superabundant quantity of blood which it may contain, and will also aid the transit of the systemic blood along the great arterial trunks. The *musculo-cardiac function* will at all times, by impeding the transit of the

blood in the arteries, increase its quantity within the left ventricle, when the heart is required to act with additional vigour;—whilst the *pulmo-cardiac function* by regulating the quantity of blood within the heart, will prevent congestion, and ward off the pernicious effects of any irregularity in the supply of blood to that organ.

By modifying therefore the inspirations, and expirations, the pulmonary vessels at the same time being able to receive various quantities of blood, the system possesses the means of restoring that balance in the circulation which is so often interrupted by moral causes operating on the heart, and by physical causes acting on the organs of respiration.

Let us first consider these phenomena separately, and as they present themselves in the healthy state of the system, which will prepare us afterwards to examine the various modifications they undergo in the diseases of the thoracic viscera; for it could not well be anticipated that any rational explanation could be given of the diseased changes in the function of an organ, until the phenomena which occur in the healthy state had been investigated.

The movements of the chest which take place during fits of laughter, and in the acts of crying, weeping, sobbing, and sighing, we shall find are

all resorted to by the system, in order to effect alterations in the *quantity* of blood both in the lungs and heart, when the circulation has been deranged by mental emotions.

Laughter—its effects on the circulation.

The deep inspirations, and the short and frequent expirations made in the act of *laughing*, have a direct influence on the heart, increasing the quantity of blood within its cavities, in the same manner as the quantity within these is increased by muscular contractions.

This condition of the heart, as might be anticipated, will vary in proportion to the violence and duration of the paroxysms of laughter. When these are moderate, the mind is only exhilarated, or to use a common expression "the heart becomes joyful," but if laughing be increased, or prolonged beyond certain limits, a series of effects more or less injurious frequently supervene. Pain in the cardiac region, and headach then come on, and if the paroxysm be immoderate, the quantity of blood propelled into the brain is such, that the intellectual powers become greatly excited, and sometimes to such a degree, as to cause their temporary aberration. Even convulsions follow immoderate fits of laughter, and I have known death take place from excessive laughter, caused by titillation.

A disturbed action of the heart is usually ob-

served in those affected with hysteria which may account for the paroxysms of laughter, the risus sardonicus, the hiccup, and all the more remarkable pathological phenomena, which are characteristic of that disease. Laughter indeed, greatly disturbs a heart which is already irritable. This was strikingly exemplified in a person who had a disease of the heart, and who could not indulge in laughing without the increased action of the heart by which it was accompanied, always causing violent headach.

Effects of Laughter on a diseased heart.

Crying,—which consists in a succession of violent and long protracted expirations, will have the effect by diminishing the circulation in the pulmonary arteries, of unloading the left heart and large arteries of any surplus quantity of blood, caused by the action of the heart having been interrupted, whether by moral causes, or from bodily pain;—hence the relief which those who suffer mental affliction, or bodily pain derive from crying.

Crying—its effects on the circulation.

From the same cause arise the great langour in the circulation, and even the pernicious effects which have frequently been known to follow the endurance of severe bodily pain without crying. A man who made no signs of great suffering, during a military flogging, dropped

Hurtful effects of not crying.

down lifeless. Another person who had a diseased heart, expired during an operation.

Effects of the screams of the infant.

The *screams* likewise of the infant which are made the moment of its birth must have a great influence on the circulation within the chest, the violent expirations powerfully contributing to propel the blood through the pulmonary vessels, which are then only for the first time called on to perform their functions.

Weeping—its effects on the Circulation.

Weeping also, which consists in irregular respirations, with or without crying, is an effort made to facilitate the pulmonary circulation, and relieve that congestion in the heart, which is caused by grief. Hence arise the baneful effects, and the sensation of fullness, and even of pain in the cardiac region, so frequently caused from not weeping when the mind has been greatly excited.

Sobbing and *sighing* appear to be movements more especially employed to relieve the head from congestion. The full inspirations which are made in these acts, by withdrawing the venous blood from the head, will assist in restoring the natural balance of the circulation both within the head and chest, when it has been destroyed by some violent, or sudden mental emotion. Sobbing and sighing must, therefore,

be considered as a wise provision which the system possesses for warding off the pernicious effects of passion, as far at least as regards the circulation in the head and heart,—for mental excitement also deranges the functions of other organs.

Effects of Grief and Rage.

In *grief,* or long protracted and severe affliction, such is the influence of the mind on the heart, that the circulation of the blood becomes extremely languid, and sometimes to such a degree as to produce syncope. The diminution observed in all the vital powers, when the female is subdued by grief, forms a striking contrast to the violent and hurried efforts to respire, which a man makes when he is enraged. Whilst the increased flow of blood and congestion in the head during rage, have often proved fatal, the diminution in the action of the heart from mental affliction, may even go so far as to extinguish life. A lady apparently in perfect health, on receiving unexpectedly the account of her mother's approaching dissolution, fell on the ground lifeless! Many similar cases are on record, and it is not long since the wife of a criminal dropped down dead, after bidding her husband a last adieu! All these physical effects of grief and rage have not escaped the observa-

Fatal effects of.

tion of those who have successfully delineated human nature, and have indeed been studiously imitated by performers in the drama.

Effects of Vomiting on the circulation.

The influence of *vomiting* on the circulation ought also to be noticed, as it is an act employed not only for the purpose of evacuating pernicious substances from the stomach, but likewise for assisting the left heart and large vessels in propelling the systemic blood when the circulation has been disturbed. The same expulsatory effort which removes the contents of the stomach must also, by the pressure of the abdominal parietes and the collapse of the walls of the chest, which take place during vomiting, have a considerable effect on the circulating apparatus, and consequently it may be observed that *spontaneous vomiting* is resorted to by the system, for the relief of some diseases connected with a disturbance in the circulation.

In the Asiatic Cholera ;

In the Asiatic Cholera, wherein the blood from a preternatural degree of viscidity, cannot be circulated with its usual facility, we observe the disease often accompanied with vomiting, and it is well known that when spontaneous vomiting does take place, its influence in aiding the circulation of the viscid blood is such, that the patient generally recovers from that formida-

ble malady;—and the importance of artificially producing vomiting in the treatment of Cholera is well established.

in febrile Diseases;

There are likewise many febrile diseases, wherein the effects of vomiting are equally manifest, and it may be remarked, that the relief which the act of vomiting affords does not arise from the evacuation of any noxious contents from the stomach, but by producing an almost immediate change in the action of the heart.

The *nausea* which precedes the act of vomiting, by diminishing the movements of the heart, must also be taken into consideration when endeavouring to account for the curative effects of emetics, and it has usually been observed, that an emetic which causes a protracted nausea is a more effectual remedy than one which produces speedy vomiting. In the use of emetics, it is, therefore, essential to discriminate whether it be requisite merely to evacuate the stomach, or to act on the organs of circulation.

in Syncope;

It may also be remarked, that vomiting frequently takes place whilst a person is recovering from syncope, being resorted to by the economy in order to assist in restoring the force of the circulation.

in Sea-sickness;

The fits of vomiting which accompany sea-sickness, likewise produce temporary relief, by

withdrawing venous blood from the head; but, as I shall subsequently point out, no permanent relief can be obtained from sea-sickness, until the person acquires a power of modifying his respiration.

in Pregnancy. The sickness and vomiting, which so frequently accompany a pregnant state of the uterus will in all probability, be also found to depend on a disturbance in the circulation, which explains the decided relief which is derived from the abstraction of small quantities of blood from the arm under such circumstances.

Effects of Coughing on the circulation. What I have said regarding vomiting, applies also to *coughing*. The act of coughing being resorted to by the system, both for the purpose of evacuating pernicious secretions from the mucous surface of the lungs, and likewise for restoring the thoracic circulation when that has been disturbed. Hence the various coughs and paroxysms of coughing which accompany diseases of the heart.

Sneezing. The act of *sneezing* like that of coughing and vomiting is not only an effort made to remove hurtful substances from the cavities of the nose, but is also resorted to by the system for modifying the circulation. By paroxysms of sneezing the violent expirations increase the velocity of the circulation and the blood is driven to the

head, thus causing hæmorrhage from the over distension of the vessels of the sneiderian membrane, in like manner as a paroxysm of coughing causes a hæmorrhage from the lungs when there has been a pulmo-cardiac congestion.

Effects of Hiccup on the circulation.

Hiccup seems to be an act connected with some disturbance in the circulation of the blood within the thorax; being usually preceded by a paroxysm of laughter, the short violent inspirations which form the most striking character of hiccup, will assist in unloading the left heart wherein blood has been congested. Hiccup is also one of the last acts of the dying, and it is a striking symptom in fatal strangulation of the intestine.

Modifications of Respiration in Running, &c.

Modifications likewise take place in the duration of the inspirations and expirations when a person makes any very powerful but short muscular effort, such as to run, leap, or raise a very heavy weight. In *running* a match, not exceeding one hundred yards, or in leaping, the exertion is accomplished during the period of one inspiration, and the long inspiration made by a paviour, or blacksmith, whilst raising the hammer of great weight, is always followed by a violent expiration accompanied with a deep and audible sigh; the effect of which is, by restoring

in raising a weight.

the balance of the circulation, to prevent congestion either within the lungs, or heart.

Sea sickness explained.

It is from a want of the power of adjustment, or co-operation in the respiratory and circulating organs, by which we can explain *sea-sickness*. Dr. Wollaston observed, that in those who did not suffer sickness at sea, their respiration was altered. In waking from very disturbed sleep, he found that his respirations were not made with the accustomed uniformity, but were interrupted by irregular pauses, with an appearance of watching for some favourable opportunity to make the succeeding effort, and it seemed as if the act of inspiration were in some manner to be guided by the tendency of the vessel to pitch with an uneasy motion.

"After I had been harrassed," (observed that ingenious philosopher,) "by sea-sickness for some days, and had in vain attempted to account for the difference between the inexperienced passenger, and those around him more accustomed to the sea, I imperceptibly acquired some power of resisting its effects, and had the good fortune to observe a peculiarity in my mode of respiration, evidently connected with the motion of the vessel; but of which, in my enfeebled state, I was unable to investigate either the cause or consequence. In waking from a state

of very disturbed sleep, I found that my respirations were not taken with the accustomed uniformity, but were interrupted by irregular pauses, with an appearance of watching for some favourable opportunity for making the succeeding effort, and it seemed as if the act of inspiration were in some manner to be guided by the tendency of the vessel to pitch with an uneasy motion.

"The mode by which I afterwards conceived that this action could primarily affect the system, was by its influence on the motion of the blood; for, at the same instant that the chest is dilated for the reception of air, its vessels become also more open to the reception of the blood, so that the return of blood from the head is more free than at any other period of a complete respiration. On the contrary, by the act of expelling air from the lungs, the ingress of blood is so far obstructed, that when the surface of the brain is exposed by the trepan, a successive turgescence and subsidence of the brain is seen in alternate motions with the different states of the chest." See Philos. Trans. 1815.

Modes of relieving Sea-sickness.

Dr. Wollaston's views of the cause of sea-sickness accord with the means that are usually resorted to for its relief. One mode is placing the body in such a position, that the weight of

the column of blood in the head shall be diminished as much as possible during the "pitching" of the vessel. The other is by modifying the respiration, to prevent congestion within the head. The horizontal position, and placing the head as much as possible to the ship's centre, mitigates the sickness according to the first principle; whilst by the common practice of tying a belt firmly round the waist, or by keeping the mouth shut, and thus limiting the expansion of the parietes of the chest, respiration is so regulated, that the balance of the circulation within the head and chest is preserved.

The disagreeable effects of the motion of a ship in disturbing the circulation of the blood, I have repeatedly known to occur in an aggravated degree, in persons who have been affected with some disease of the heart. Such individuals suffered from sea-sickness, not only with unusual severity, but had also many uneasy sensations continue, more particularly that of the ship's motion for a considerable time, even for weeks after having come on shore.

Those who are not accustomed to travel rapidly in a carriage, are also apt to suffer from sickness, or some unpleasant feelings in the head during a journey, and I have also known instances of uneasy sensations and feelings of

the motion of the carriage continue for several days, in those who have had an affection of the heart.

The art of Diving;

On a similar adjustment of the respiratory and circulating organs consists the art of *diving*. The power of remaining under water depends on the diver previous to immersion inspiring the greatest quantity of air which the lungs can contain, without the distension of the air cells being such as to interrupt the circulation through the pulmonary vessels. Thus he can remain under water till the air which has been inspired is no longer fitted for the arterialization of the blood; whereas a person who has not from experience acquired such a power of adjusting the thoracic viscera, cannot remain under water, from the feeling of suffocation immediately succeeding submersion, which is caused by congestion of blood within the pulmonary vessels.

provisions for, in certain Animals;

In those animals which can remain under water a considerable time and in the class of amphibia, we find that there are peculiarities of structure contrived in order either to avert pulmonary congestion or to supply the lungs with an extra quantity of air. Thus, in the

in the Otter;

otter the inferior vena cava is enlarged and tortuous, so that when the animal is under

water that vein receives a portion of the returning blood and retains it until respiration is again performed and the pulmonary circulation be established. And in some *reptiles* the trachea where it enters the lungs forms capacious vesicles which serve as a reservoir, enabling the animal to remain under water as long as the air which they contain is sufficient for the arterialization of the blood.

in some Reptiles.

Swinging must likewise have the effect of alternately increasing and diminishing the pressure of the blood within the head according to the differences in the weight of its column in the various attitudes which the body assumes when rising and falling in the swing. Whilst the head is ascending there will be little or no change in the degree of pressure which is made on the brain, as far at least as any alteration in the weight of the blood's column is concerned, but when the feet ascend and the head is placed downwards, then a column of blood will press on the brain with a gravity in proportion to the elevation of the extremities and depression of the head.

Effects of Swinging on the Circulation.

Such increase of pressure on the brain is quite sufficient to account for the giddiness which many experience in swinging, whilst those who do not suffer such uneasy feelings

are able to avoid them by an involuntary effort in breathing, by which the action of the respiratory organs is modified,—for, as has been already pointed out, a certain adjustment in the inspirations withdraws venous blood from the brain at the moment when the column of arterial blood is exercising an undue pressure.

How the balance of the circulation is preserved in different postures.

In the same manner we can account for the power which some individuals acquire of "standing on the head" as tumblers and actors on the stage, without suffering giddiness or headach. The balance of the circulation in such varied positions of the body is preserved by the inspirations and expirations being so modified that no surplus quantity of blood is permitted to go to the head but finds a receptacle in the pulmonary vessels.

Circulation modified according to the habits of different animals.

Contrasted with the uneasy feelings experienced from changes of posture or unusual motions of the body, it is interesting to observe the perfection in the circulating organs of some of the lower animals, that enables them to perform the various movements, which their habits and necessities require. The rapid motions and varying positions of the body of those which live on trees or amongst rocks—the flight of birds—the habits of amphibious animals—all require certain peculiarities in the structure and func-

tion of the respiratory and circulating organs, which are not necessary for the human species.

Subject concluded.

Having endeavoured to point out that the pulmo-cardiac and musculo-cardiac functions, along with the influence which respiration exercises on the circulation, unfolds the means which nature employs for supplying at all times the heart with a requisite quantity of blood, as well as for preventing those congestions to which the thoracic viscera are constantly exposed, it may be anticipated that a knowledge of these functions will enable us to account for many phenomena in the diseases of the thoracic viscera which have hitherto been inexplicable. Indeed in almost every affection of the heart we shall find the function of respiration more or less disturbed,—the diseases of the heart influencing the functions of the lungs, inasmuch as the diseases of the lungs alter the condition of the heart.

In conclusion I may remark, that it is by the musculo-cardiac and pulmo-cardiac functions combined, and the influence of the inspirations and expirations variously modified, by which the respiratory organs can under all circumstances alter the supply of blood not only to the heart and lungs but also to the *brain;* and

therefore when we extend our researches to their various phenomena, we must always keep in mind the influence and dependence which the functions of these vital organs have on each other—and that for duly regulating the circulation of the blood, it is requisite that the brain, as well as the heart, and the lungs, should constantly preserve an accordance and cooperation in all their actions, and that whenever their harmony is interrupted, many pathological conditions supervene, characteristic of and depending on irregularities in the distribution of the sanguineous fluid.

Reciprocal influence of the Heart and Brain.

Hitherto we have been contemplating the great function of the circulation of the blood as carried on by a simple hydraulic engine, but like every other apparatus forming a component part of the animal structure, the heart is under the influence and dependence of the nervous system.

Influence of the Brain on the Heart.

'Tis true though we do not comprehend what the "mysterious principle of life" is, yet we know it emanates from the nervous system, and that for its exercise and due influence on the various organs, certain physical conditions are requisite. We have indeed sufficient evidence

that the nervous energy, sensorial power, or by whatever abstract terms it may be denominated, depends on and is modified by the quantity of blood and by the regularity of its circulation within the brain, the energy of the brain, like that of other organs, depending on its supply of blood. No more indeed can the brain perform its functions without blood than the heart carry on the circulation without the concurrence of the brain.

Effects of the Passions.

That the action of the heart is influenced by mental emotions is well known, and it must have been this influence, particularly the effects of joy and grief which led the ancients to place the seat of these passions in the heart.

Effects of Pain.

The action of the heart is increased by long-continued pain, and when that has been sudden or very severe, such as often happens in accidents, in gun-shot wounds, or in surgical operations, the "shock" is sometimes so great as to render the action of the heart scarcely perceptible,—or even diminish it to such a degree as altogether to destroy life.

How these are explained.

This influence of the brain on the action of the heart, physiologists have accounted for by attributing the involuntary movements of the heart to the influence of the great sympathetic nerve or ganglionic system, whilst the par vagum,

from its connection with the lungs, stomach, and all those organs associated with the function of respiration explains how the action of the heart is under the influence of the passions.

The quantity of blood within the head is altered.

This dependence of the brain on the circulation of its blood is exemplified by the effects which changes in its quantity have in causing various states of mind, such as watchfulness—irritability—or even mental aberration. Hence too arise those various shades of intellectual energy which may be observed at different times in the same individual.

Causes of Watchfulness and Sleep.

The artificial means which are frequently resorted to for producing watchfulness are therefore such as increase the action of the heart and consequently increase the supply of blood to the brain; whilst the usual means that are employed to promote sleep are such as tend to subdue the action of the heart, and thus diminish the quantity of blood within the head. Tea, coffee, and wine, therefore, by increasing the action of the heart, induce watchfulness, whilst antimony and narcotics, by diminishing the vigour of the heart, dispose to sleep.

Means of inducing Sleep.

Sleep is also induced by increasing the quantity of blood in other regions of the body, and thus diminishing the quantity of blood in the

head. The practice of immersing the feet in warm water to which has been added a stimulating ingredient as vinegar, mustard, or common salt, disposes to sleep, diminishing the quantity of blood within the head by increasing the supply to the extremities. Sponging the body with diluted vinegar, spirits, or salt water, by producing a glow on the skin also relieves the internal organs of a certain quantity of blood; and taking fluids into the stomach likewise disposes to sleep by diverting blood to that organ.

When the intellectual powers have been kept in a state of excitement, the heart's action is often so much increased that sleep is interrupted, if not altogether prevented, and therefore instead of endeavouring to sleep immediately after any active mental employment if the body be kept for a while in a state of repose, the excited vascular system will be calmed and tranquillized. This effect of mental excitement is remarkable even in children, for it may be observed that when a child falls asleep immediately after any unusual excitement, its sleep is generally disturbed and unrefreshing. The judicious nurse therefore allows the excited system to be tranquillized before she permits the child to fall asleep.

Causes of Stupor.

Contrasted with watchfulness or disturbed sleep, is *stupor* or an unnatural disposition to sleep,—a state caused by a very different condition of the circulation in the brain to that which has just been described. In place of an increased supply of arterial blood,—the cause of intellectual excitement,—there is, in stupor, a congestion of venous blood within the head, a state wherein the veins are preternaturally distended, analogous to the congestion so frequently occurring in the veins of other organs, particularly those of the abdominal viscera.

The Sleep of Disease.

Sleep is also liable to other disturbed conditions, most of which appear to depend either directly or indirectly on the state of the circulation in the brain, the phenomena of which are however very different from the excitement caused by an increased supply of arterial blood or from the stupor produced by venous congestion.

After describing the sleep of health,

> "That silent power whose gentle sway
> Cheers every anxious thought away,"

an elegant writer, Macnish, reverses the picture and paints with his finished pencil the sleep of disease. "It is short, feverish, and unre-

freshing, disturbed by frightful or melancholy dreams. The pulse is agitated, and from nervous excitation there are frequent startings and twitchings of the muscles. Night-mare pressing like an incarnation of misery upon the frame. Imagination distempered by its connection with physical disorder ranging along the gloomy confines of terror, holding communication with hell and the grave, and throwing a discolouring shade over human life."

Like other functions of the economy, sleep may therefore be either natural or diseased, and as various changes to which it is liable may be accounted for by changes in the circulation, the different conditions which it presents will afford important signs in many diseases of the heart, irregularities in the venous circulation within the head being referable to those of the right and alterations in the arterial circulation indicating changes in the left heart.

Reciprocal influence of the Heart and Digestive organs.

The Heart influenced by the Stomach;

Besides those alterations in the movements of the heart which are produced by the influence of the brain and nerves, the action of the heart is also changed by causes which depend on

its consent or sympathy with other organs. Hence the action of the heart is influenced by disturbances in the digestive organs. The sickness produced from nauseating food diminishes the vigour of the heart's action, whilst stimulants and cordials increase the force of the circulation; and many persons have the action of the heart much disturbed by taking particular kinds of food, or food which they cannot digest.

and by the Intestines.

The retention of an unusual quantity of excrementitious matter in the large intestines sometimes creates a great disturbance in the heart's action, whilst at other times this sympathy is exemplified by the effect of a purge; which diminishes the vigour of the action of the heart and creates as much depression as would be produced in some persons by a copious blood-letting.

The Stomach influenced by the Heart;

The functions of the heart greatly influence the digestive organs, in as much as the heart is disturbed by affections of the alimentary canal. The influence of the heart's action on the stomach is strikingly illustrated by the immediate effect of sudden mental emotion or muscular exertion immediately after a meal, the congestion thus caused in the heart diminishing that quantity of blood in the vessels of the sto-

mach, which is requisite for accomplishing the process of digestion.

The effects of Vegetable and Minerals on the Heart.

The influence of some vegetable as well as mineral substances, when received into the stomach, on the action of the heart, is very remarkable, and is of great importance to be kept in mind when treating the diseases of this organ, irregularities in the action of the heart which have been taken for serious diseases being sometimes traced to the accidental employment of such substances in the treatment of other complaints.

Vegetable substances.

One common cause of a disturbance in the action of the heart is the use of *tea*, particularly green tea, which in many has a powerful influence on the action of the heart. *Coffee* also produces great nervous excitement from its effect on the action of the heart, and I have observed some persons whose hearts were diseased suffer much from the use of coffee. A gentleman of a plethoric habit could at any time produce hemorrhage from his nose by drinking coffee.

Opium also when administered in improper doses frequently disturbs the heart's action, and by producing restlessness, prevents its anodyne effect on the nervous system.

Digitalis too has been much employed to

subdue the action of the heart in those diseases wherein that organ has been preternaturally excited; and *belladonna* acts in like manner very powerfully on the heart.

The effects of *hellebore* in disturbing the action of the heart are so remarkable that soldiers and seamen who wish to be discharged from the service have been frequently known to employ it in order to counterfeit a disease of that organ.

There are as I shall have occasion afterwards fully to explain other substances which mitigate or subdue the heart's action,—and these form an important class of remedies for the treatment of its diseases.

Mineral substances.

Of the mineral substances the preparations of *lead*, of *antimony* and of *iron* have the most powerful influence on the actions of the heart. The acetate of lead has been much used to check hemorrhage; and the preparations of antimony so powerfully subdue excited action of the heart that they have been often employed in place of blood-letting for the cure of inflammatory diseases.

Mercury also has a decided influence on the action of the heart. In many instances however mercury produces most serious effects on the heart's action, and there are many persons in

whom even a very small quantity of that mineral has a deleterious influence on the circulating organs.

Of the Blood.

In prosecuting our researches on the function of the heart we are naturally led to extend our enquiries to the blood, that fluid for the distribution of which throughout the system, the heart is specially assigned. "Out of the Heart are the issues of life."

Heart influenced by the quantity of Blood;

The blood being the stimulus to the heart, any variation in its quantity or quality must modify its action, and produce changes in its function as the right or left heart happens to be affected.

whether venous or arterial.

A certain quantity of arterial blood being necessary to enable every organ to perform its particular functions, these will be necessarily disturbed whether that quantity be increased or diminished; or whether there be any alteration in the circulation of the venous blood.

Of arterial blood.

If, for example, as I have already remarked, there be an additional flow of arterial blood to the brain from an increased action of the left heart, the intellectual functions become excited; and if from any cause the quantity of arterial blood be diminished, the powers of the mind are then proportionally enfeebled, or they may com-

pletely cease, as takes place in syncope when the depletion has been carried to a great extent.

Of venous blood.

On the other hand when from any disturbance of the circulation in the right heart, the veins of the brain become preternaturally distended, symptoms supervene of a very different character to those caused by an increase in the arterial blood, the intellectual powers becoming sluggish and inert, producing stupor or torpor.

These two opposite conditions of the vascular system may be produced in other organs, as well as in the brain, by changes in the action of the heart, and all such conditions afford, we shall subsequently find, useful diagnostic symptoms in diseases of that organ.

Alterations in the quantity of blood within the heart how caused.

The heart's action, I have already stated, even in a state of health is constantly varying. The position of the body—the slightest muscular exertion—the state of the stomach—the condition of the nervous system,—each produce more or less temporary changes in the movement of the heart,—changes which are the immediate effects of differences in the quantity of blood within its cavities.

By alterations of posture.

If the body be in the erect posture the heart requires to exert a greater force in order to propel the arterial blood to the head, than when it is placed in the recumbent position—hence

one cause of the changes in the number of the pulsations of the heart. And when the quantity of blood within the heart is increased by muscular movements, the heart's impulse as well as the number of its pulsations are much increased.

By muscular action.

The presence or absence of food in the stomach, by altering the quantity of blood sent to that organ, also increases or diminishes the action of the heart.

By the state of the Stomach.

All these causes of a temporary increase of blood or of congestion in the heart are important to observe, as they illustrate many pathological phenomena which have not been accurately explained.

Where there exist differences in the quantity of blood within the heart, when from any change in the structure either of the right or of the left heart, these cavities are unable to expel their contents with their wonted force,—or when the blood cannot freely circulate through the lungs,—or even when from any great depletion the quantity of the whole mass of blood is much diminished, —then under any of these circumstances the heart's action will be more or less disturbed.

By alterations in the structure of the Heart and Lungs.

If the blood does not undergo the necessary changes in the lungs, the difference in its *quality* must modify the heart's action, and when either from malformation or disease, the venous and

Heart influenced by the quality of the blood.

arterial blood become mixed, changes take place in the movements of the heart.

There are also changes which take place in the qualities of the blood in certain diseases, such as in scurvy, cachetic diseases, and in persons whose constitutions have become much debilitated,—all of which alter the action of the heart.

The changes of the blood in Asiatic cholera affect in a particular manner the action of the heart. The escape of its serous parts into the alimentary canal, and the extreme thickness of what remains in the veins, render its circulation extremely difficult, and cause that congestion in the heart, as well as in the head and portal system which form such remarkable features of that fearful disease.

Effects of these on the Brain.

The symptoms which such differences in the quality of the blood produce on the functions of the *brain* as well as on the heart ought also to be accurately distinguished from those which arise from changes in the quantity or in the velocity of the current of blood within the head.

Of the Pulse.

Having considered the influence which the arterial system exercises over the blood's circulation in the heart, we shall next enquire what

influence the heart's action has on the circulation of the blood in the arteries.

Heart's influence on the Arteries.

Though changes may take place in the functions of the smaller arterial ramifications of an inflamed part, without any recognizable alteration in the action of the heart, yet changes in the heart's action usually produce alterations in the action of the larger arteries,—all which are indicated by the pulse.

Importance of a knowledge of the Pulse.

As changes in the pulse denote corresponding alterations in the heart's movements, they will therefore afford important diagnostic signs in the diseases of that organ, and an intimate acquaintance with these, along with those changes which take place in the respiratory organs, are, it will be found, as indispensable for establishing a correct diagnosis in diseases of the heart as a knowledge of the impulse and sounds of the heart itself. At all events, the facility with which the pulse can be examined renders the various changes which it presents in diseases of the heart most important.

Until the celebrated Laënnec pointed out the changes to which the sounds of the heart are liable, we had no other means of ascertaining the alterations in the functions of this organ, than by observations on the pulse together with the effects which the changes in the circulation cause on

the other systems, more especially on the respiratory organs, on the brain, and on the organs of digestion ;—and imperfect as the means of diagnosis might then have been, I am persuaded that fewer and less serious mistakes were committed, than we now see made by those who look only to the physical signs of the diseases of the thoracic viscera, and disregard that general assemblage of symptoms which accompany those affections, and which arise from the disturbance of other organs or other systems of the economy.

Whilst the opinions of physiologists remain so unsettled as to the causes of the sounds of the heart,—the mode by which the blood is propelled through the arterial canals,—and the functions which even the coats of the arteries perform, it cannot be expected that the various alterations in the functions of the arteries as indicated by the pulse can be very satisfactorily explained.

It is however essential to observe the various changes which take place in the pulse in the different diseases of the heart, and endeavour to discover their correspondence with alterations in its structure and functions.

Observation has indeed shown that the pulse

Pulse altered from various causes.

is altered from a variety of causes, and that certain states of the pulse not only accompany particular diseases, but also indicate the use of particular remedies. We can by the pulse readily discriminate those diseases which require an antiphlogistic treatment from those in which a stimulating system is necessary. In the first instance the irritable state of the heart's parietes may cause an increase in its impulse which is tranquillized by diminishing the quantity of the stimulating blood, whilst in the latter case the pulse may be rendered more frequent by a debilitated state of the body,—the left ventricle in such cases, not being so capable of emptying itself, sooner dilates and consequently is the sooner stimulated to contract, a greater number of contractions being requisite to propel a sufficient quantity of blood throughout the system.

From obstruction to the circulation.

We further know that all impediments to the circulation influence and modify the pulse. If the blood's stream be impeded, along the aorta,—or from passing from the right auricle into the right ventricle—or if there be any impediment to the pulmonary circulation, either from disease in the vessels themselves, or from alteration in the structure of a portion of the lungs,—under any of these circumstances we find an alteration

in the pulse, some of which changes are so remarkable as to be sufficiently characteristic of particular diseases.

Alterations in the pulse very numerous.

On comparing the different changes in the pulse, which authors have described, with an enumeration of the diseased sounds of the heart, we are struck with the great numerical preponderance in those of the pulse, and if both alterations in the heart's sounds and changes in the pulse assist in establishing the diagnosis of diseases, and serve as indications for their treatment, those presented by the pulse certainly afford the most abundant data.

Pulse not altered in all affections of the Heart.

It is of consequence however in considering this matter to recollect what has been already mentioned—that diseases of the heart may sometimes exist without any apparent change in the pulse, though we never find the pulse changed without a corresponding deviation in the action of the heart. Thus when the heart's action is violently increased, as takes place in a thoracic aneurism, the great increase in its impulse which the heart acquires does not affect the pulse but is lost, or as it were destroyed, in overcoming the resistance which the aneurism causes to the circulation. It may be stated as a general observation that in congestion and in all cases where the heart's impulse is increased in order to over-

come an obstruction to the circulation, the increased impulse will not necessarily affect the pulse. This apparent discrepancy in the actions of the heart and indications afforded by the pulse, is remarkable when the aortic valves are diseased or when the calibre of that artery is diminished,—though the heart is compelled to act with an increased vigour to overcome such obstructions to the free circulation of the blood, yet the force of the pulse is diminished; and I shall afterwards have occasion more fully to explain that in some diseases of the heart, particularly where there is a preternatural quantity of blood or congestion, the pulse is by no means a safe guide for the employment of blood-letting.

In order to show how extensive are the variations of the pulse and with what nicety they have been discriminated I have drawn up a table of such varieties as have been generally defined and characterised by distinct terms.

See Appendix I.

By bringing together these various denominations of the pulse, the importance of distinguishing them from one another will be the more apparent, whilst it will also show how difficult it is, and what extended observation it must require, to be able to recognise all these variations, and draw the practical as well as pathological con-

clusions each may indicate. It is just as difficult to discriminate by the sense of touch all those nicer shades of difference in the pulse as for the eye, the ear, or the tongue to perceive those slight differences in qualities of bodies which are discernible by these several senses. Indeed great experience and habits of accurate observation are requisite to enable us to detect the more minute changes to which the pulse is liable and refer each to particular conditions of the heart, and capillaries and these difficulties will account in some measure for the contradictory descriptions of the pulse in the same diseases which have been given by different authors. We should likewise be aware, that observations on the pulse, however accurate, serve little purpose in distinguishing diseases of the Heart, unless when viewed conjointly with the changes in the other systems of the economy which usually accompany those affections.

Of the Impulse of the Heart.

By placing the hand upon the chest we are able to feel the movements of the Heart, and on applying the ear to the cardiac region we can perceive two distinct sounds.

The *shock,* or as it is more technically called,

the "Impulse," of the Heart, so evident in a healthy person to the sense of touch, varies greatly in its intensity, so that it may be taken as a measure both of the increase and diminution in the force of the action of the Heart.

The differences in the impulse of the Heart are very considerable in its healthy condition, these differences arising either from peculiarities in the natural form, or in the thickness of the walls of the chest,—from differences in the bulk of the Heart, and also from differences in the natural vigour of the constitution.

"The *force* of the Heart" observes Senac, "is constantly varying. The vicissitudes of age, the impressions of surrounding bodies, food, or abstinence, all influence its movements." In order therefore to be able to form a just estimate of the variations in the impulse of the Heart, caused by diseases, we must first become acquainted with its changes in healthy individuals.

We shall be in a particular manner struck with a great increase in the impulse when the Heart becomes gorged with blood, as takes place after any violent exercise, and with a diminution in the impulse or even with its becoming imperceptible, in those who are suffering from debility or temporary exhaustion, as we see exemplified in a state of syncope.

Having by the exercise of the sense of touch become familiar with all those temporary alterations to which the impulse of the Heart is constantly liable, we are then prepared to examine its variations in diseases.

Of the Sounds of the Heart.

The sounds of the Heart are in accordance with its different movements, vary in different conditions of the healthy subject, and are changed by alterations in the Heart's structure.

The sounds may be changed in intensity or in duration. In some individuals they are sharp and acute, in others they are more or less dull, or even scarcely audible. One of the sounds termed the "first sound," is usually flat whilst the "second sound" is more sharp, clearer, and shorter than the first.

The sounds are perceived to follow each other in rapid succession, after which there is a pause,—and the proportions, of the intervals between the sounds, constituting the *rhythm*, are variously altered in diseases.

The sounds become altered whenever any change takes place in the thickness, or density of the parietes of the Heart,—or when alterations take place in the form of its cavities. They may likewise be altered, from changes in the structure

of the parts surrounding the Heart, and they may be either increased or diminished in intensity —changed in duration,—only one of the sounds altered—entirely new sounds produced—or the intervals between them may be changed.

Much has been written and many unnecessary and cruel experiments have been made on living animals in order to find out the causes which produce the sounds of the heart. But as Magendie has justly observed when alluding to the discordant opinions on this subject, " the results of physiological enquiries have not been in proportion to the number of authors who have written on the subject,—on the contrary you are disturbed by contradictions of the most glaring nature, or bewildered between a mass of theories and explanations which have no existence but in the minds of the inventors."

APPENDIX

AND

EXPLANATION OF THE PLATES.

APPENDIX (A.)

The Fibro-Cartilaginous Structure of the Heart.

" Most authors," observes Bichât,* " have described very inaccurately the mode in which the aorta is united with the heart. The following is the manner. The internal membrane of the left heart, after having lined the ventricle, is continued to the mouth of the aorta, separates from it, and forms by its folds the three semilunar valves; after which it is continued along the artery through its whole course. It is this internal membrane which is the only bond of union between the artery and the heart. The proper or fibrous membrane of the artery is not intermingled with the muscular fibres of the heart, but the extremity of the artery is cut out into three semicircular festoons, each festoon corresponding with one of the sigmoid valves. These festoons do not extend quite so far as the fleshy fibres of the ventricle; there is between them an interval of two or three lines, which is closed only by the internal membrane. Between each festoon, and consequently between the valves, we perceive three small triangular empty spaces, which are also covered with the membrane. To distinguish this structure it is necessary to dissect accurately the origin of the aorta from without, and to remove the adipose tissue which surrounds it. Then on tracing the artery

* Anatomie Générale, tom. ii. p. 259.

and its connection with the ventricle, and on examining it against the light, the reunion one with the other, having previously raised the valves, we can then distinctly perceive, from the transparency of the internal membrane, and from the opacity of the three festoons which commence the aorta, the structure which I have described. It follows that if the artery be accurately dissected from without, we detach from below upwards the internal membrane which forms the great canal of the systemic circulation, the artery is separated entirely from the heart. This complete separation of the aortic fibres from those of the heart, would be a strong presumption that their nature is not the same, if many other considerations did not establish that opinion."

APPENDIX (B.)

The Trajet of the Coronary Arteries and Veins.

"There is some dubiety, with regard to the manner in which the Heart itself is supplied with blood, which involves the function of the sigmoid valves, and the arterial sinuses. The arteries which go to other viscera, the liver for instance, and the kidney, &c., plunge into them, and then ramify outwards toward the surface. But the coronary arteries run along in the deep tendinous grooves between the auricles and the ventricles. This tendinous ring in the left side of the heart, for instance, gives origin or fixture at its lower border, to the muscular fibres that pass downwards from it, and from

the left ventricle; while another set go off from its upper order, to form the auricle, leaving a considerable sunk space, two or three lines in breadth, from which no muscular fibres rise. In this fossa the coronary artery lies secure, being defended on the one side by the thick upper edge of the ventricle, and by the under edge of the auricle on the other. As the artery proceeds onwards, following the curve of the groove, it gives out branches downwards, from its under side to the ventricle, and similar branches upward to the auricle. These divide in the substance of both auricle and ventricle to great minuteness."*

APPENDIX (C.)

Current of the Blood in the Coronary Arteries and Veins.

"The veins, in almost every other part of the body, decrease like the arteries, as they proceed from the heart; though their currents run contrary to that of the arteries. But in the heart, the currents of the large branches of the coronary vein, which lie alongside of the coronary arteries, and fill up the greater part of the groove, flow in the same direction with that of the arteries; so that by the time the two arteries have got round, in their grooves, to the posterior side of the heart, where, greatly diminished in size, they meet and

* See Observations on the Heart and on the Peculiarities of the Fœtus, by James Jeffray, M. D. Professor of Anatomy in the University of Glasgow, 1835.

send down their last branches towards the apex, the veins that have accompanied them, increased greatly in size, having received, as they came along, all the branches which both ventricles and auricles had to give, unite and form a short trunk, that has been called the coronary sinus; which, after running a little way, till beyond the edge of the septum, penetrates obliquely to the right, though the wall of the auricle, into which, at its inferior left corner, it pours its contents. It might have entered, and had it been a vein anywhere else, it would have been made to enter, nearly where the coronary arteries had come to touch the heart, and probably between the two, had it not been, that in travelling to that point, it would have been increasing as it went, while the artery was already there, so large as almost to fill the groove, so that it must have stood out a bump, that would have been unprotected. As matters are ordered, the vein is largest where the artery is least, whereby there is room in the groove for both, and all chance of injury is avoided."

It should also be considered that the trunk of the vein, lying over the artery, between the right auricle and ventricle, is less than that of the left side; probably because many of the branches, instead of coalescing to form one large vein, terminate directly in the right auricle and ventricle.

But, though the trunks of the coronary arteries and vein be thus protected, their branches, in the substance of the ventricles and auricles, must suffer compression, when these are in systole or contraction; and as the auricle is in diastole, when the ventricle is in systole, blood will pass up freely into the substance of the

auricle, when the ventricle is in contraction, and as freely down into the ventricle, when the auricle is in contraction; so that although each of them receives blood, only during half the time of the heart's beat, the coronary trunks must be receiving blood constantly from the aorta; else they could not be prepared to furnish a regular and alternate supply.*

APPENDIX (D.)

The Anastomosis, and modes by which some Arteries are protected from the pressure of Muscles during their contractions.

The Plates are intended to show different modes by which a uniform supply of blood is secured to different organs both in man and in different tribes of animals, when from the function of the organs, the regularity in the supply of blood is liable to interruption.

To effect this purpose I have stated that there are several peculiarities in the distribution of the arterial system, which are employed either separately or conjointly, according as the functions of the organ may require. The peculiarities met with in the distribution of the arteries are their inosculations or *anastomoses*—their sub-division into a number of branches, and subsequent reunion forming a plexus or a *rete mirabile*—their *tortuosities*, and certain *modes of protection* from the pressure of muscles during their contraction. By these different contrivances organs are secured in the

* Jeffray's Observations on the Heart, p. 4 and 5.

various movements and positions of the body, as well as during the performance of their various functions with the necessary quantity of blood, and likewise the blood is sent to them with the requisite momentum.

Plate I. gives some examples of the more remarkable anastomoses of arteries in organs whose incessant motions would necessarily interrupt the circulation did they not receive a supply of blood from several different arterial trunks.

Figure 1, shows the Coronary Arteries of the Lips, the circle round the mouth receiving inosculating branches from the facial, from the nasal, and also from the submental arteries. By this anastomosis it is evident that the lips will be at all times supplied with a due quantity of blood in all their varied movements. The eyelids also afford an example of a similar inosculation of the arteries.

Figure 2, represents the inosculations of the Coronary Arteries of the Heart. In this organ, so important to life, we find that two modes are employed for securing it with a regular supply of blood,—there is not only a free anastomosis of the coronary vessels, but their trunks pass along the surface of the heart in such positions as has been already fully explained, so that the circulation through them cannot be interrupted during the contractions and dilatations either of the auricular or of the ventricular cavities.

Figure 3, shows the inosculation of the Arteries of the Stomach, and how every part of that viscus will be supplied with blood during its vermicular movements.

Plate II. gives some further examples of remarkable anastomoses in the Arterial system.

Figure 1, shows the Palmer Arteries by the inosculation of which all parts of the hand are supplied with blood in its varied positions, and in grasping.

Figure 2, represents the inosculation of the Arteries of a portion of Intestine, the influence of the vermicular movements and varied positions of the alimentary canal being thus guarded against, and the free circulation of the blood never interrupted.

Figure 3, exhibits the inosculations of the Arteries in the Iris, an interior circle passing round the margin of the pupilar opening, forming festoons, and an exterior circle passing round the circumference of the iris. By this anastomosis and curvatures of the ciliary vessels a uniform supply of blood is secured to the iris during the constant contractions and dilatations of the pupil.

Plate III. gives examples of some of those contrivances which nature has recourse to in order to protect certain arteries from being compressed, and the free passage of the blood through them interrupted, either by the contractions of the active organs of loco-motion, or by particular attitudes of the body.

Figure 1, exhibits an example of this provision in the Arteries of the Brain. There are not only four separate arterial trunks for supplying this important organ with blood, all which anastomose and form the basilar artery, the vertebral arteries, unlike the carotids, are protected from the pressure of the cervical muscles during their contractions by passing along the bony canal in the cervical vertebræ.

Figure 2, represents the right vertebral artery passing along the bony canal formed in the transverse processes of the vertebræ of the neck, by which it is completely

protected from the pressure of the cervical muscles during their contractions.

Figure 3. The coronary arteries of the heart, like the arteries of the brain, not only inosculate freely with one another, but they are also protected from the influence of the contractions of the ventricles and auricles by that simple and no less beautiful contrivance already explained. In the vertical section of the Heart, represented in this diagram, from the relative position of these vessels with the muscular fibres of the parietes of the auricles and ventricles, it is evident that neither their contractions nor relaxations can have any influence on the transit of blood in the coronary vessels. (*a a a*) are the muscular parietes of the right, and (*b b b*) the parietes of the left ventricle (*c c c*), and (*d d*) are the mouths of the right and left coronary arteries and veins. The fibres of the ventricular parietes are distributed in such directions that they cannot during their contractions compress these vessels.

Plate IV. contains examples of arteries in animals where different contrivances are resorted to for the protection of their circulation.

Figure 1, exhibits the Brachial Artery of the Sloth, which vessel, besides being protected by passing through a bony canal, like in the Feline tribe, this artery divides into many parallel branches, which afterwards unite into one trunk, so that when the animal is suspending itself on the branch of a tree, which it often does uninterruptedly for many hours, the pressure of the muscles caused by the prolonged contractions of the limbs cannot impede the circulation in the arteries of the extremities; whilst also the pressure on the limb against

the resisting branch of a tree cannot, from its transit through the bone, compress the artery. Here then we have in this animal two provisions in the distribution of the arteries—one for securing the circulation against the long protracted contractions of the muscles of the limb, the other to guard the artery from the compression to which it is exposed when the animal clings to a tree by grasping with its limbs.

This peculiarity in the distribution of the brachial artery of the sloth was first described by Sir A. Carlisle, although he has given a most unphilosophical explanation of its function.

" In the Lemur tardigradus," he observes, " the axillary and iliac arteries, at their entrance into the upper and lower limbs, are suddenly divided into a number of equal-sized cylinders, which occasionally anastomose with each other. They are exclusively distributed on the muscles; whilst the arteries sent to all parts of the body, excepting the limbs, divide in the usual arborescent form; and even those arteries of the limbs which are employed upon substances not muscular, branch off like the common blood vessels. I counted twenty-three of these cylinders about the middle of the upper arm, and seventeen in the inguinal fasciculus.

" This fact appeared at first too solitary for the foundation of any physiological reasoning; but, having since had an opportunity of prosecuting the enquiry, among animals of similar habits and characters, *I have been encouraged to hope that the result may eventually assist in the elucidation of muscular motion.* The *Bradypus tridactylus*, or great American sloth, has a similar distribution of the arteries of the limbs to that already

described in the *lemur tardigradus*. The communications of these vessels with each other are more frequent than in the *lemur tardigradus*, and their number is considerably greater. I counted forty-two separate cylinders upon the superficies of the brachial fasciculus; and, from the bulk of the fasciculus, I estimate there were twenty or more concealed in the middle. The lower extremities has its arteries less divided, and they are of larger diameter; I observed only thirty-four branches in the middle of the thigh; and the first series of ramifications were larger than the subsequent ones. May not this have some relation to the greater distance of the lower limb from the heart? The extremely slow movements of the *Bradypus tridactylus* are sufficiently known among natural historians.

"The *Bradypus didactylus* has its arterial system distributed in some degree like the *Bradypus tridactylus;* but the brachial artery in the upper limb is much less sub-divided, and in the lower limb, the arteries of the plexus afterwards divide a few times in the arborescent form. It may be worthy of remark that this correspondence of arrangement, in the arteries of the lesser sloth, bears a striking analogy with the structure and habits of the large American sloth; the movements of the *Bradypus didactylus* being universally represented quicker than those of the *Bradypus tridactylus.*

"In all the quadrupeds before mentioned, the other blood vessels, as well as the nerves, presented the common appearances."*

* See Account of a peculiar Arrangement in the Arteries distributed on the Muscles of slow-moving Animals, by Anthony Carlisle. Philos. Transact. 1804.

Mr. Langstaff, who has examined this structure, and pointed out the passage of the artery through a canal in the humerus, (a fact which had not been observed by other anatomists,) suspects that besides the divisions of the trunk of the artery into many branches, the canal of the trunk itself is continued through the centre of them. If this observation be correct, we then have an example of a *third* provision for regulating the circulation in the limbs; when the animal is not grasping or clinging with his limbs, the *rete mirabile* is not wanted; and then the circulation will be able to go on directly through the trunk of the artery.

Mr. L. found it so difficult to separate the vessels composing this Plexus, that he has not been able satisfactorily to ascertain the distribution of the trunk; if however the vessel was injected with wax, and the soft parts eroded by an acid, the true manner in which the artery is distributed would then be distinctly pointed out.

Some of the preparations are preserved in the Museum of the Royal College of Surgeons, and others remain in the Langstaffian collection.

Figure 2 represents in a fœtus calf the plexus formed by the internal carotid artery, called by Galen the *rete mirabile.* (*a*) is the top of the common carotid, (*b*) the external carotid arteries, (*c*) several arteries which supply the place of the single internal carotid in man, (*d*) numerous small serpentine branches into which these arteries are subdivided in their progress through the cranium (*e*) these branches joining again into (*f*) the principal trunk of the internal carotid artery within the head, and which afterwards divides into branches, resembling those in man.—(Monro.)

Figure 3, represents the Humerus of the Cat, in which, as in the lion and other of the feline tribes, and also in the sloth, the brachial artery passes through a canal (*a*) formed in the bone, in such a manner that when the animal is grasping its prey, and which it is often obliged to do for a very lengthened time, the circulation in the brachial artery can go on without interruption.

Figure 4, is a diagram of the vertebra of a shark, wherein, besides the spinal canal (*a*), there is a foramen (*b*) for the passage of the aorta, and another for the cava, which canals in these animals are intended to protect the vessels from the effects of the extended movements of their tail, (*c*) is the body of the vertebra.—(Grant)

APPENDIX (E.)

Haller's Account of the Increase both of Circulation and of Respiration by Muscular Movements.

"She has likewise," observes Haller, "placed the *veins* near the muscles, which, by their swelling, compress the interposed veins; and since every pressure on the veins, on account of their valves, determines the blood towards the heart, therefore all this force is entirely employed in accelerating the return of the blood to the heart. Hence that wonderful quickness, redness, and quick respiration after muscular action." (See also Appendix H.)

"Respiration has a remarkable consent with the action of the heart. When the pulse is frequent the breathing is hurried, when the pulse is slow and gentle respiration is scarcely to be observed. When we breathe more frequently than usual, the pulse becomes more frequent, when the breathing falls back to its usual rate, the heart's action again gradually subsides. *The means by which this consent is established are unknown.*"—Mayo, *p.* 82.

APPENDIX (F.)*

A new mode of increasing the Heart's action for restoring the powers of life in persons apparently dead from drowning, or in syncope. By JOHN HYSLOP, *Esq. Surgeon.*

"Some years ago I had occasion to bleed a lady, and abstracted upwards of thirty ounces of blood, whilst she was in bed. About three hours afterwards, on attempting to rise she fainted. The family being in great alarm I was sent for, and when I got to the bed side I found that another practitioner was in attendance. He said to me, "Your patient is dead." The basin of blood remained still on the table, and I was in great uneasiness on account of the lady's condition, and I confess I also

* This interesting paper had been prepared by Mr. Hyslop, long before his decease, addressed to the Royal Humane Society, and by the permission of a near relative I am enabled to insert it in this work. J.W.

dreaded the effect of the largeness of the bleeding. Spirits of ammonia had been sent for but deglutition was suspended; a flexible tube was sent for, and I became very much alarmed.

In this state of anxiety of mind and without having any precise purpose in view at the time, I desired her husband, who was almost frantic, to assist me in raising up her head and shoulders from this supine position. She gradually resuscitated, and in three or four minutes she became quite revived. I again visited her late at night, when she said she had great pain in her arms, and she thought that her husband and I had grasped her arms too tightly.

On returning home and reflecting on the circumstances of this case, I concluded that pressure (quite unintentional however) on the brachial arteries, by impeding the circulation, and causing congestion, must have excited the action of the heart.

On making the experiment, I found that by pressing the brachial artery, the pulse though it gradually beat faster and faster continued still small and thready, and when the pressure was removed it became very full and continued so for some time.

I can at any time raise the pulse in this way. On repeated trials I find that the pulse being first felt so as to ascertain the progress of the pressure it runs nearly thus:—

In $3\frac{1}{2}$ minutes it rises from 68 to 74
5 - - - 68 to 78
7 - - - 68 to 80

So that in seven minutes twelve beats in the minute can be gained. Is there any medicine known which can do

this in so short a time? How valuable then is this fact!

It was only yesterday that an eminent anatomist called on me. He doubted the fact. I convinced him by stopping the circulation in his right arm, when in nine minutes his pulse rose fourteen beats in the minute. I measured his pulse, it was:—

75, and in $3\frac{1}{2}$ minutes it rose to 83
in 5 - - - 85
in $8\frac{1}{2}$ or 9 - - 90

As the laws in the animal system sometimes call in the act of pressure, I conclude that to imitate nature in that respect and in other instances of disease, especially in such as proceed from great exhaustion, they may be (after the knowledge of this fact) successfully treated.

Before I conclude I have only to say—that if the tourniquet was known formerly to be of use in disease, I can surely affirm it is *not used* at the present day, nor for the thirty-six years that I have been in practice in London either at public hospitals or in private practice.

If the patient is thin and delicate, the force of the operator's thumb will be sufficient to produce the necessary pressure. But if the patient be more masculine, a tourniquet must be applied. It may be objected, by saying, "but where is a tourniquet to be had?" A simple and effectual one can be made of a neckcloth or pocket-handkerchief, and a bit of stick, a pencil case, or the handle of a pocket knife.

I have, on this occasion, pointed out the good effects to be derived from this practice, as regards a sudden stimulus to the heart, when in cases of suspended animation,—in cases of persons apparently dead from drowning

and in syncope. But much is left to be said, of its use, in various other instances where the sanguiferous system requires quick attention, and a remedy fortunately always at hand.

A very few remarks on the means of restoring persons in such melancholy cases, will suffice, when it is recollected that I am addressing myself to the Committee of the Royal Humane Society, whose information on the subject must be not only minute, but also very extensive.

1. When the body has been taken out of the water no time is to be lost—delay—mere delay is often fatal. The action of the heart is to be assisted—or if gone, to be speedily restored.

2. Mechanical distension of the lungs, independent of any influence on the blood from the atmosphere, is instantly required—because the heart cannot empty itself through the medium of the pulmonary arteries while the air-cells are in a collapsed state, which is not often the case. Therefore, the best way is, at once to make an opening in the wind-pipe with a pointed knife, and blow air into the lungs with a straw or a bit of tobacco-pipe, or with the operator's mouth. Delay will be found far more dangerous than the rudeness of this slight puncture.

3. As the ventricles are in this state gorged it is proper to open a vein. But this must not be done at either of the arms, for a reason I shall presently give. It may be conveniently done in the neck—or if no blood flows, at once to open the temporal artery. Much blood is not required, and its flow can be soon stopped by completely dividing the vessel.

4. It is now that *stimulants* to rouse the action of the powers of the system are of use. But—where are they? Not on the sea-shore, or on the banks of a river! Time too, is precious, a very little delay is death, the powers of life are already almost gone—the pulse cannot, perhaps, be felt at either wrist, the motion of the heart cannot be perceived, or is merely fluttering. But let us suppose many remedies at hand, it has often been found all of them, or many of them, hitherto in use, do little good, and the patient's fate appears to be sealed. It is at this particular point of time that I consider the mode which I have stated in regard of forcing the renewal of the action of the heart is particularly applicable."

APPENDIX (G.)

Macnish's Explanation of Yawning.

"I have alluded to *yawning* as one of the symptoms which ushers in sleep; but it follows as well as precedes this state. It seems an effort of nature to restore the just equilibrium between the flexor and extensor muscles. The former have a natural predominancy in the system; and on being fatigued, we, by an effort of the will, or rather by a species of instinct, put the latter into action for the purpose of redressing the balance and poising the respective muscular powers. We do the same thing on awaking, or even on getting up from a recumbent posture; the flexors in such circumstances

having prevailed over the extensors, which were in a great measure inert."*

APPENDIX (H.)

Wollaston's Account of the Effects of Exercise.

"The explanation which I am about to offer of the effects of external motion upon the circulation of the blood, is founded on a part of the structure observable in the *venous system*, the mechanical tendency of which cannot be doubted. The valves which are every where dispersed through those vessels, allow free passage to the blood, when propelled forward by any motion that assists its progress; but they oppose an immediate obstacle to such as have a contrary tendency. The circulation is consequently helped forward by every degree of gentle agitation. The heart is supported in any laborious effort that may have become necessary by some obstacle to its exertions; it is assisted in the great work of restoring a system which has recently struggled with some violent attack; or it is allowed, as it were, to rest from a labour to which it is unequal, when the powers of life are nearly exhausted by any lingering disorder."†

* Macnish on Sleep, p. 28.

† "On the Salutary Effects of Riding and the other Modes of Gestation." Philosophical Transactions, 1809.

APPENDIX (I.)

Terms by which the Varieties and Modifications of the Pulse are designated.

Full.	Thready.	Irregular.
Voluminous.	Contracted.	Quick.
Small.	Vibratory.	Frequent.
Elastic.	Bounding.	Accelerated.
Tense.	Jerking.	Slow.
Hard.	Thrilling.	Feeble.
Wiry.	Quivering.	Faltering.
Strong.	Fluttering.	Soft.
Incompressible.	Unequal.	Weak.
Compressible.	Intermitting.	Languid.

APPENDIX (I.)

Sir Everard Home's account of the Structure of the Lungs.

" The first new fact discovered in the course of this enquiry was, that although the common minute injection used by anatomists for filling the blood vessels, when thrown in by the trunk of the pulmonary artery, while the cells of the lungs are empty, returns again by the trunks of the pulmonary veins, yet when thrown in by the veins, it is not returned by the trunks of the arteries."

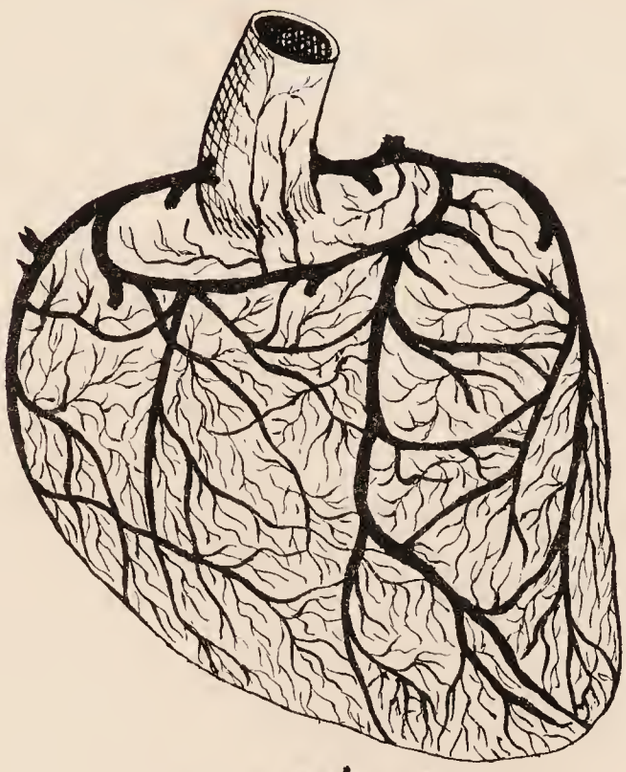
" Another fact was discovered; that during the momentary distension of the air-cells, an interruption is pro-

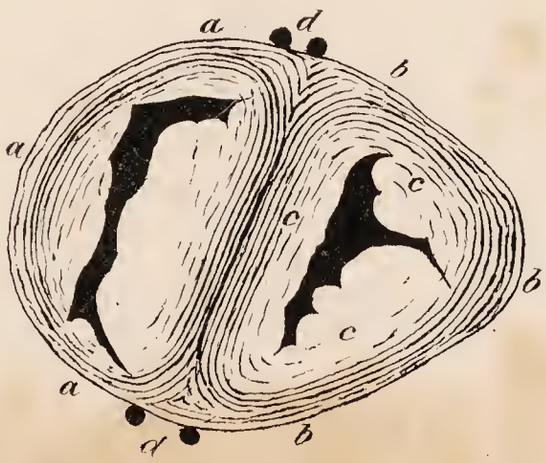
duced between the arterial and venal circulation in the lungs, the blood being carried no farther than the small arterial branches surrounding the air-cells."

The following is the account of the mode by which Sir Everard Home displayed this structure.

"The cells of the Lungs were filled with quicksilver, to show their utmost capacity, and the parts were afterwards immersed in rectified spirit, to prevent the cells from collapsing, when the quicksilver was allowed to escape. When the internal cavity of a single cell was exposed, immediately behind its internal membrane, the branches of the pulmonary artery, injected with red wax, were seen ramifying, as arteries do in common; these were accompanied by branches of the pulmonary vein, larger in proportion than those of the arteries, more numerous, and having valves, at apparently regular intervals, to prevent regurgitation of their contents. Besides the arteries and the veins, there were innumerable absorbents opening into the cavity of the cell; their valves were at very short distances, and, in their course, in the interstitial substance between the cells, they accompanied the veins. When the terminal branches of the pulmonary artery were traced, the injection was found to have stopped some way before the artery's termination, and the space beyond was filled with gas. The substance of the lungs, interstitial to the cells, when dried became transparent, and was found to be composed of a smaller order of cells, with transparent coverings, that freely communicated with one another, as well as with the cavity of the large cell they surrounded."*

* Phil. Trans. 1827.

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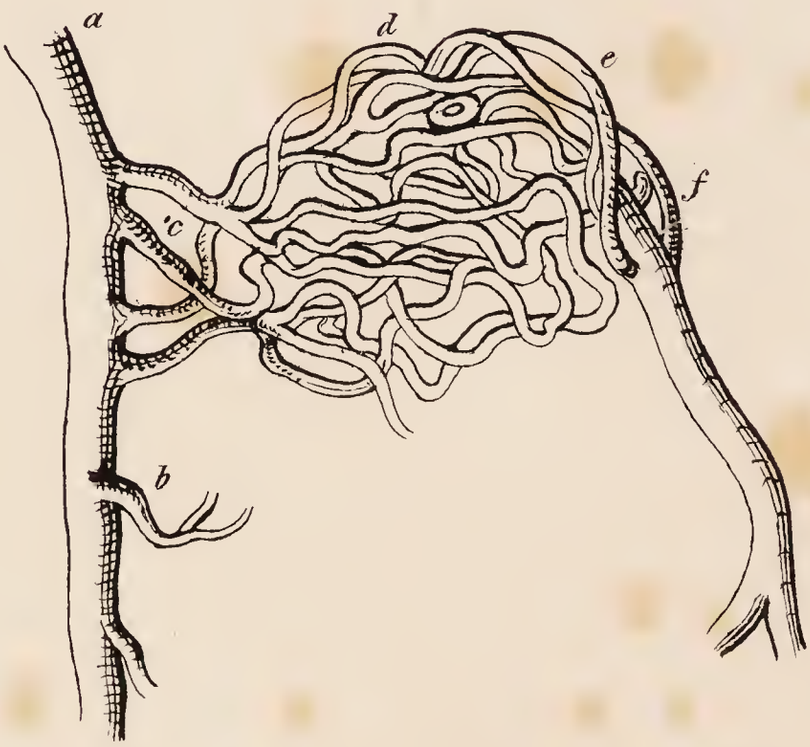
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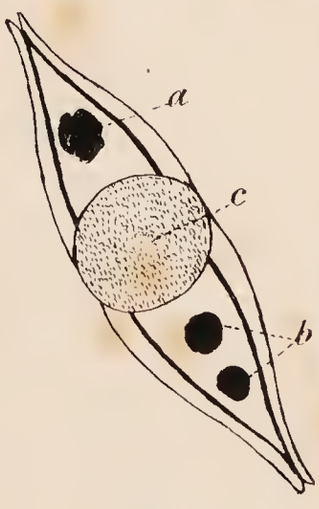
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